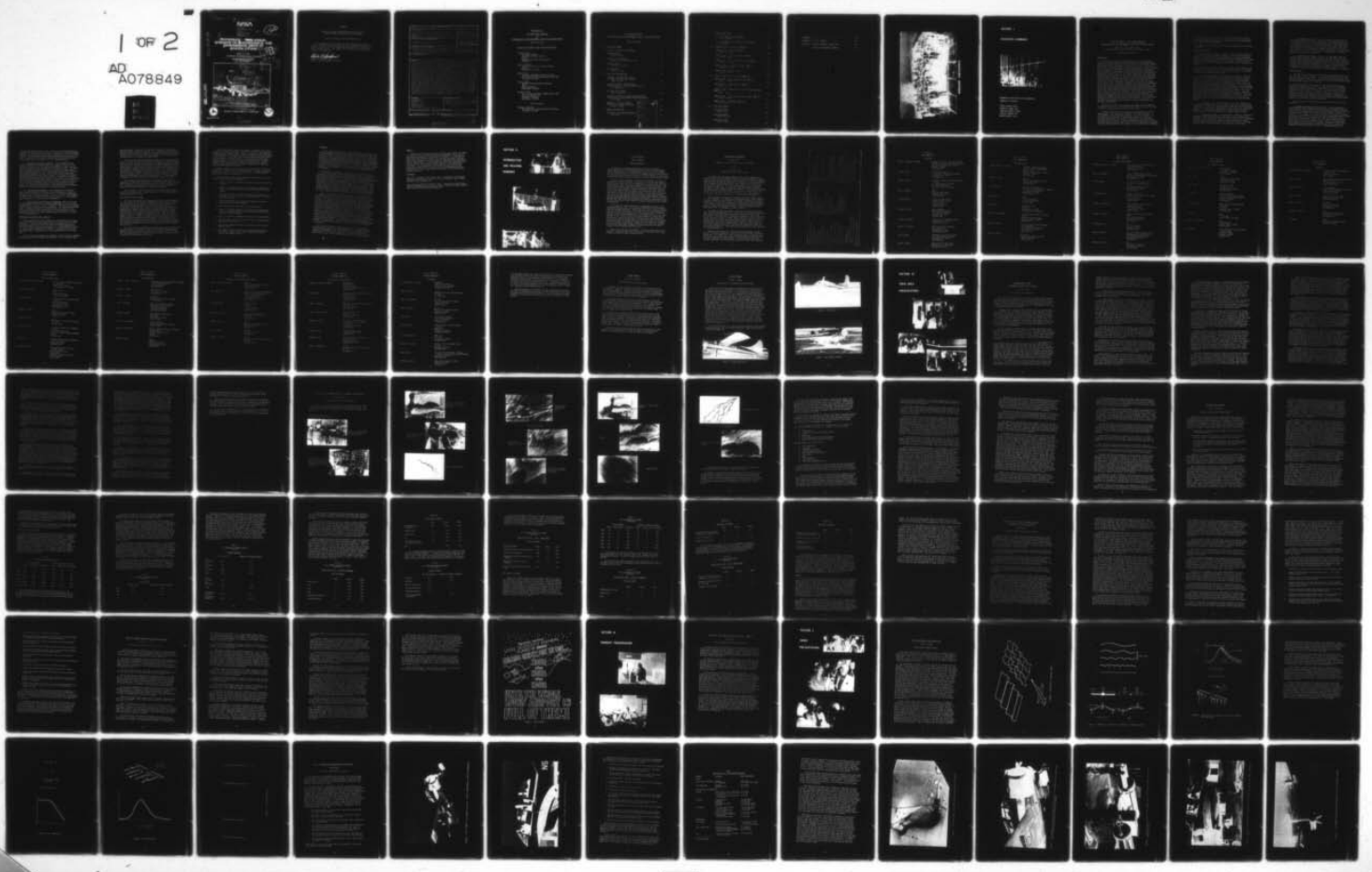
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Conference publication.

NASA
National
Aeronautics and
Space
Administration
NASA CP-2104

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AD A078849

PROCEEDINGS: THIRD ANNUAL WORKSHOP ON METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

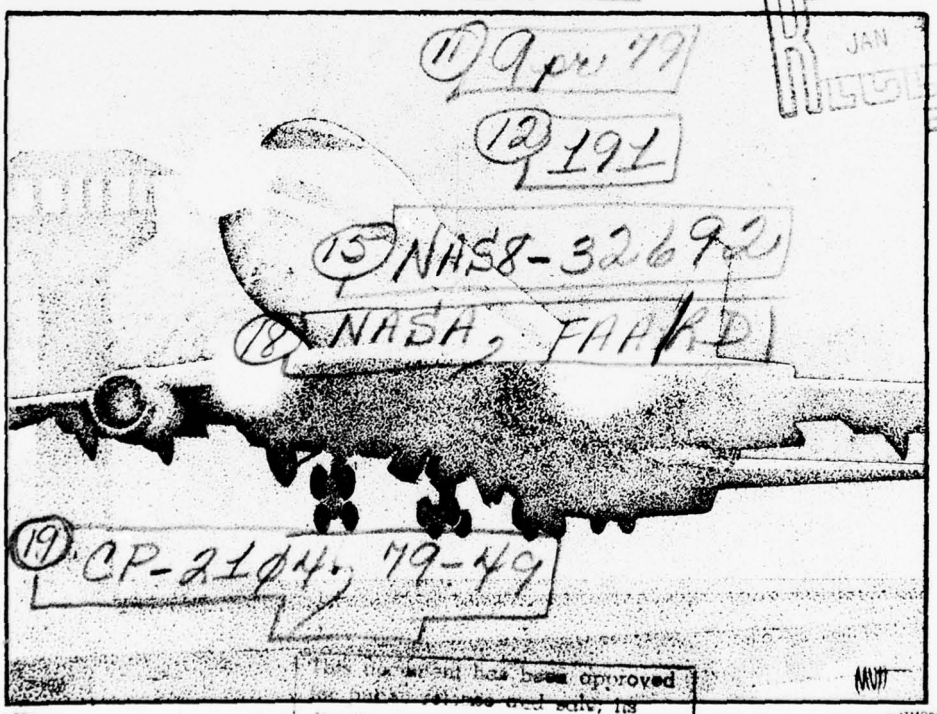
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APRIL 3-5, 1979

UNIVERSITY OF TENNESSEE SPACE INSTITUTE

EDITORS: DENNIS W. CAMP
WALTER FROST

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11 Apr 79
12 191
15 NAS8-32692
18 NASA, FAA-RD
19 CP-2104; 79-49

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TECHNICAL EDITOR: REBECCA A. DUROCHER

FAA-RD-79-49

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APPROVAL

PROCEEDINGS: THIRD ANNUAL WORKSHOP ON METEOROLOGICAL
AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

Edited by Dennis W. Camp and Walter Frost

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

Charles A. Lundquist

CHARLES A. LUNDQUIST
Director, Space Sciences Laboratory

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA CP-2104 /FAA-RD-79-49		

4. TITLE AND SUBTITLE	5. REPORT DATE
Proceedings: Third Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems	April 1979
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT #
Edited by Dennis W. Camp and Walter Frost	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
The University of Tennessee Space Institute Tullahoma, Tennessee 37388	11. CONTRACT OR GRANT NO. NAS8-32692
	13. TYPE OF REPORT & PERIOD COVERED

12. SPONSORING AGENCY NAME AND ADDRESS	
NASA/Marshall Space Flight Center, Alabama 35812 DOT/Federal Aviation Administration, Washington, D.C. 20553 DOC/National Oceanic and Atmospheric Administration, Rockville, Maryland 20850	Conference Publication 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The proceedings of a workshop on meteorological and environmental inputs to aviation systems held at The University of Tennessee Space Institute, Tullahoma, Tennessee, April 3-5, 1979, are reported. The workshop was jointly sponsored by NASA, NOAA, and FAA and brought together many disciplines of the aviation communities in round table discussions. The major objectives of the workshop are to satisfy such needs of the sponsoring agencies as the expansion of our understanding and knowledge of the interaction of the atmosphere with aviation systems, the better definition and implementation of services to operators, and the collection and interpretation of data for establishing operational criteria, relating the total meteorological inputs from the atmospheric sciences to the needs of aviation communities. The unique aspects of the workshop were the diversity of the participants and the achievement of communication across the interface of the boundaries between pilots, meteorologists, training personnel, accident investigators, traffic controllers, flight operation personnel from military, civil, general aviation, and commercial interests alike. Representatives were in attendance from government, airlines, private agencies, aircraft manufacturers, Department of Defense, industries, research institutes, and universities. Full-length papers from invited speakers addressed the topics of Training, Flight Operations, Accident Investigation, Air Traffic Control, and Airports and are contained in the proceedings. These topics constituted the fixed committee titles, while floating committees were titled Winds and Wind Shear; Icing and Frost; Atmospheric Electricity and Lightning; Fog, Visibility and Ceilings; and Turbulence. Committee chairmen's reports on the results and conclusions of the committee meetings are given.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Aviation Safety Meteorology Air Traffic Control Training Flight Operations General Aviation Aviation Weather Research and Services	Document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161 STAR Category 47

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	190	

MSFC - Form 3292 (Rev. December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151

387070

PROCEEDINGS OF

THE THIRD ANNUAL WORKSHOP

ON

METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

April 3-5, 1979

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THIRD ANNUAL WORKSHOP

ON METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

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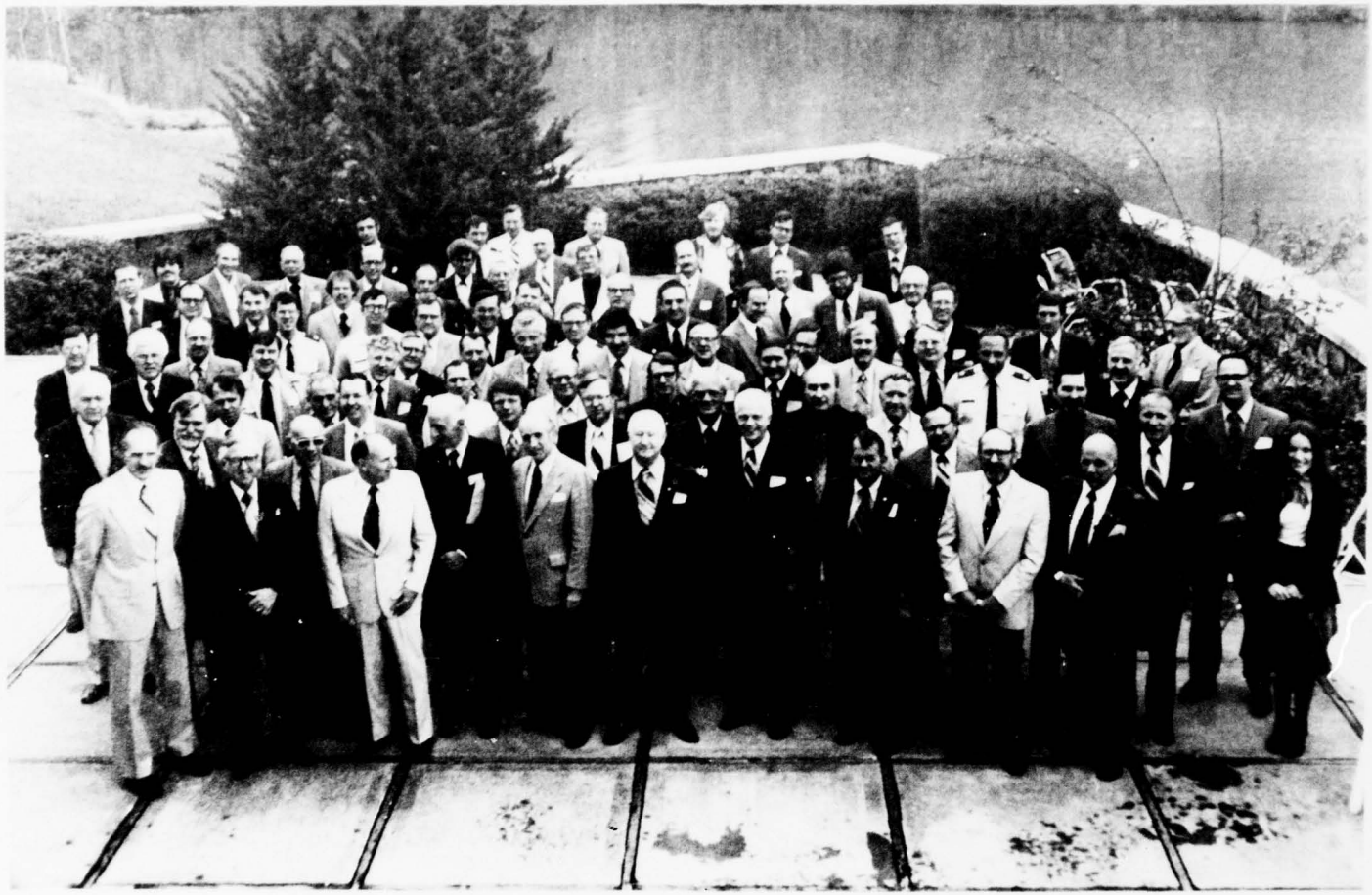
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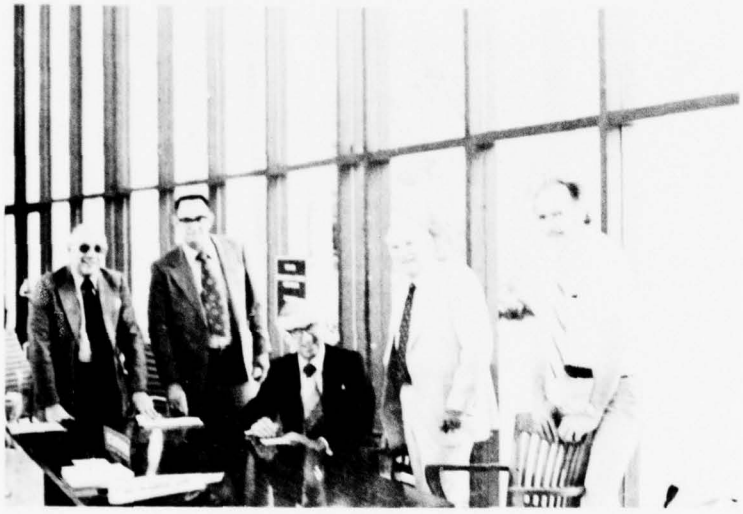
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WORKSHOP PARTICIPANTS

SECTION I

EXECUTIVE SUMMARY



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FROM LEFT TO RIGHT:

JOHN H. ENDERS, NASA
DENNIS W. CAMP, NASA
JOHN W. CONNOLLY, NOAA
JOSEPH F. SOWAR, FAA
WALTER FROST, UTSI

EXECUTIVE SUMMARY: THIRD ANNUAL WORKSHOP ON METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

Dennis W. Camp, Walter Frost,
John W. Connolly, John H. Enders, and Joseph F. Sowar

Organization Committee

INTRODUCTION

The Third Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems, held at the University of Tennessee Space Institute on April 3-5, 1979, was sponsored by the NASA, NOAA, and FAA. The purpose of these workshops is to bring together the various segments of the civil and military aviation community, air traffic personnel, pilots, aeronautical educators, researchers, accident investigators, aircraft designers, and general service personnel with meteorologists and atmospheric scientists in round table discussions to establish and identify the weather needs of the aviation community and to determine how these needs might best be satisfied. Some insight into the theme of the workshops was provided by John Enders in his "Welcome Remarks": "The First Annual Workshop provided an opportunity for a 'mix' of researchers, pilots, designers, forecasters, air traffic and weather service specialists, and airline management to express their individual and collective views on weather problems in the aviation system. The Second Annual Workshop held last year focused on detailed examination of the most severe weather problems identified at the first workshop, with a view towards seeking consensus on appropriate public and private sector actions to solve these problems. Out of those discussions last year it became apparent that training and education throughout the system were important to achieving a better understanding of weather hazards and weather-tolerant designs and operations. This Third Annual Workshop has been organized to explore the training and education questions in more detail in the context of design, operations, and accident investigation."

Results of the first two workshops are presented in proceedings of Camp and Frost, 1977; and Frost and Camp, 1978. Similar proceedings for the third workshop are presented in this report.

Committee efforts for the workshop were concerned with several hazard areas: [(1) winds and wind shear, (2) icing and frost, (3) atmospheric electricity and lightning, (4) fog, visibility, and ceilings, and (5) turbulence] and how they impact (1) training, (2) flight operations, (3) accident investigation, (4) air traffic control, and (5) airports. Floating committees consisting of individuals with expertise in the area of the first five committees interacted in round table discussions with experts in the second list of committees.

Each of the committees was asked to conduct discussions which would yield information in its topic areas useful in forming recommendations to improve training and education in aircraft design, aircraft operations, and accident investigation.

Summaries of the committees' findings are presented in the following sections.

WINDS AND WIND SHEAR

The title to this section is clearly indicative of two major continuing problems for the aviation community. The problem for general aviation is the need for more wind observations, more accurate wind forecasts and more frequent wind information for altitudes below 10,000 feet. Low level wind shear is more of a concern (problem) to high performance aircraft during take-off and climb out and in approach and landing.

The Winds and Wind Shear Committee considered the problems in the context of several interrelated solution methods; namely, (a) sensing or probing, (b) forecasting, (c) information exchange, (d) information utility, and (e) education and training.

a. Sensing or probing: It was generally agreed that the state of the art for measuring winds and wind shear is advancing. However, concern was expressed by the Accident Investigation Committee that perhaps too much attention is being placed on gust front conditions while other areas such as below the thunderstorm, frontal zones, and low level jet stream conditions are being neglected. The Air Traffic Control Committee felt that emphasis should continue on the development of both ground-based and airborne wind shear detectors. They also felt that research should be conducted in the near vicinity of the shear to determine penetration and transit operational factors. Research should continue on the effort to determine the intensity of wind shear the various types of aircraft can withstand. The intensity should be expressed in some sort of numerical value which a pilot can use to determine whether or not his aircraft can safely penetrate the shear region.

b. Forecasting: For general aviation it was the consensus of the various committees that the twice daily winds aloft forecasts were inadequate. In fact, the Flight Operations Committee and the overview paper on flight operations recommended a return to the four times daily forecasts. It was also recommended that observed winds be used to update the winds aloft forecasts and thus improve their accuracy.

c. Information exchange: An improvement is needed in information exchange in order to help aviators make the decisions necessary to accomplish safe flight and to help controllers pass on vital information. There was a note of caution, however, expressed by the Air Traffic Control Committee to insure that pilots and controllers are not being provided more information than they can absorb at a given time.

d. Information utility: In order to insure the optimum use of information, it must be accurate and timely. This point was amplified by H. Grady Gatlin, ATA, in his overview paper on flight operations; "...since upper air data are collected only every 12 hours, the inadequate number of observations leads to errors in the winds aloft forecasts used for flight planning and consequently to less than optimum fuel consumption." The importance of this information is clearly stated by the title of Gatlin's overview paper, "Needed Weather Information Where It Belongs--In the Cockpit."

e. Education and training: The Training Committee stated the problem in this manner, "A common problem...was the difficulty experienced in teaching airmen to understand and use the resources available for reporting and forecasting weather conditions." In John R. Colomy's overview paper entitled "Meteorological Input to General Aviation Pilot Training," he states that, "Educators must develop a meteorological presentation that positively motivates a student to learn." If this is done then no doubt a considerable part of the problem will be solved.

ICING AND FROST

The need for and importance of the work being accomplished in ice and frost was vividly portrayed in the banquet presentation by the well known and illustrious Max Karant. His discourse was an amazing, if not somewhat legendary, narration concerning a flight he made from Washington, DC, to Wichita, Kansas, a few years ago.

The significance of this subject to the ground operations was emphasized by Daniel Ginty in his talk concerning "Effect of Weather Conditions on Airport Operations." The cost of ice, snow, and frost relative to time, safety, and finances is such that we can no longer accept it as something we can live with, but as a problem that must be solved by better forecasts, planning, equipment, or whatever is necessary. Thus, it is imperative that all elements of the community closely coordinate their efforts to solve the ground operations problems caused by ice and frost to ground operations.

The Icing and Frost Committee classified their efforts into four categories:

a. Effects on general aviation aircraft: Three problem areas were identified with suggested solutions including recommendations for research and training. The first problem discussed was that of airframe icing, with the recommendation that a practical method is needed for protecting the airframe. This entails research on the use of ice-phobic coatings. It is interesting to note that the Training Committee expressed the opinion that it is not known exactly what instructions a pilot should receive concerning airframe ice. The next problem was that of ice on the airfoil. This problem could be solved if an inexpensive frost removal technique could be developed. Research on this problem should properly be concerned with establishing the severity of the aerodynamic penalties created by frost. Development of effective

training requirements would include a review of existing programs and knowledge in order that pilots can be instructed as to the best methods by which to deal with the frost problem. Carburetor icing is the third problem. The recommendation from the committee was that the best solution is prevention. This entails training and retraining on how to recognize the problem and what to do if a problem develops.

b. Effects of air carrier aircraft: Icing problems the air carriers experience are mainly engine ice ingestion and tail icing (primarily while in a low altitude holding pattern), runway ice and snow, and overnight frost accumulated on a parked aircraft. The Icing and Frost Committee indicated training as probably the best overall answer to these problems. That, coupled with some possible certification changes needed for the tail icing problem, some research and development needed for the frost on the airfoil problem, and improved icing forecasts should solve these problems. The need for a better forecast was expressed by Daniel Ginty in his paper on airport operation, where he stated, "A good timely detailed weather forecast can give us time to muster our equipment and personnel and to prepare our plan of action for that particular operation." With regard to the removal aspect, the Icing and Frost Committee stressed the need for continued research on improved techniques for ice and snow removal.

c. Icing and frost forecast: The importance of forecasts to aviation, as indicated by the Icing and Frost Committee, is readily seen by the fact that it is a repeat topic, having been included and reviewed in the first two workshops. Further, as we all know, whenever any discussions on weather and its effects are held, it is inevitable that forecasting is a topic of prime importance.

d. Icing and frost terminology and symbology: Most of us share the importance of this topic as we have wondered what is meant by the subjective terms "trace," "light," "moderate", and "heavy" as we contemplate a flight into possible icing conditions. In view of this dilemma, which illustrates the need for standarization, the Icing and Frost Committee recommends that standarization of terms relative to icing be an integral part of a larger standarization program for all facets of aviation meteorology.

ATMOSPHERIC ELECTRICITY AND LIGHTNING

The audio and visual effects used by H. Grady Gatlin in his overview paper concerning flight operation put this subject area in proper perspective. Even with the subject matter in proper perspective, a sobering thought comes to mind; one that the Training Committee and Air Traffic Control Committee considered, i.e., the tendency for pilots to accept problems caused by such factors as atmospheric electricity and lightning as a characteristic of the system which must be "lived with."

In the discussions between the Atmospheric Electricity and Lightning Committee and the Flight Operations Committee, several important needs

were recognized. There are; (1) the need for both ground-based and airborne lightning detection systems, (2) a reporting system to aid in identifying the effects of lightning, (3) better forecasting techniques, and (4) similar to the icing and frost problem, a need to improve the standardization of communication (terminology).

The Air Traffic Control Committee pointed out a very serious problem "...for aircraft and for ground-based elements for the Air Traffic Control System. With increased reliance on computer processing in both aircraft and ATC elements, susceptibility of these computers and their power sources to the voltages and currents induced by lightning must be eliminated. Neither the aircraft nor the Air Traffic Control System can tolerate a sudden and total computer outage." A similar problem indicated by this committee is the lack of flight experience for composite structures relative to bonding and the continuity of shielding especially with regard to digital avionic systems. The ATC Committee recommended continued research and development on these problems.

The Accident Investigation Committee pointed out the need for additional information on lightning "...for present technology aircraft and for advanced aircraft employing fly-by-wire control systems." This committee also pointed out the need for training accident investigators concerning the effects of lightning on aircraft.

The Air Traffic Control Committee also noted that improved forecasting of lightning areas is badly needed, as is the case with many other meteorological topics.

FOG, VISIBILITY AND CEILINGS

This area also suffers from inadequate forecasts and observations. The Fog, Visibility and Ceilings Committee put it even more strongly, "Our committee was consistently confronted with the problem of the deterioration of NWS aviation forecasts over the past ten years. Concern was voiced that the forecasts are too broad, and more precise information is needed, especially the beginning and ending times of meteorological events significant to aircraft operations." In what could be taken as a contrasting comment by Alan I. Brunstein in his overview paper on Accident Investigation he said, "The accuracy of weather forecasts is always a concern, but unfortunately, in the cases covering the 5-year period being discussed, more often than not it was not possible to make such an assessment. It can only be said at this time that in about 45% of the cases, the forecasts were considered to have been substantially correct or the weather was slightly better than forecast."

In his presentation, Brunstein also showed that fog and low ceiling was the cause of or a factor in 1,352 fatal accidents experienced by general aviation in the United States during the period of 1973-1977. This was approximately 28% of the total fatal weather-related accidents by general aviation during this period.

One of the problems relative to weather information and its utilization in general was admirably stated by the Accident Investigation Committee in its summary report, "There is a problem in the timeliness of observed weather information and PIREP information being transmitted to the cockpit." If we couple this observation with one made by the Training Committee in their report, a truer picture of the overall problem emerges. The Training Committee commented that, "A common problem which recurred was the difficulty experienced in teaching airmen to understand and use the resources available for reporting and forecasting weather conditions."

Perhaps a solution to this problem could follow one of the recommendations of John Colomy in his overview paper: "Flight instructors should also attempt to provide real experience in flight operation during low ceilings or visibilities."

Some additional comments and recommendations made by various committees of the workshop are noteworthy:

a. There is a need for automatic observations at general aviation airports.

b. There is a need for some type of retrievable recording capability in the Automated Low-Cost Weather Observation System (ALWOS).

c. Field tests should be conducted on the two most promising techniques for fog dispersal after NASA completes its present fog dispersal work.

d. Visual Flight Rules (VFR) should be examined for adequacy and revised if no longer adequate.

e. Research should be continued in slant visual range.

f. There is a continuing need for informative but nontechnical articles on aviation weather to keep general aviation pilots current on aviation weather.

g. There is a need to standardize reporting of aviation weather.

h. Airlines should consider cooperative efforts to upgrade their meteorological services.

i. The aviation community should ask the NWS for more aviation weather support.

j. The Congress should be made aware of the continued decline of aviation weather services and recommendations made to reverse this downward trend.

TURBULENCE

In an effort to establish a common definition of turbulence, the Turbulence Committee stated their definition of turbulence, "The small-scale fluctuation of the wind due either to the effects of mechanical (shearing) forces or buoyant (convective) forces or both acting simultaneously." To further eliminate confusion in their discussions they stated the difference between wind shear, turbulence, and up/downdrafts, "...turbulence produces rapid aircraft oscillations (shaking or small-scale pitching and yawing), wind shear is a wind discontinuity producing a change in airspeed (increase or decrease) while up/downdrafts cause a gain or loss of altitude." All three can and frequently do occur simultaneously.

A generalized statement of turbulence problems was put forth, "...it was evident that aviation technology has moved far ahead of the technology relating to the prediction and detection of turbulence." With regard to the detection of turbulence, it is noteworthy to indicate what Don Wood had to say in his overview paper on traffic control. As a result of an NTSB recommendation, air traffic controllers have implemented a system using input from NWS radars for "...determining several levels of intensities of precipitation or turbulence." New airborne equipment is being tested to meet the requirements of a 6-7 minute warning of a clear air turbulence encounter which was stated by the Accident Investigation Committee. The present on-board radar will give a greater warning time with regard to thunderstorm activity.

Three of the problems mentioned with regard to turbulence are the same ones discussed in other topic areas. First is that of forecasting accuracy; many of the warnings issued turned out to be false alarms. The converse of this is also encountered, that turbulence encounters occur when no advance warning has been given. If a good on-board turbulence detector can be developed then the need for turbulence forecasts will not be as critical except for general aviation where in all likelihood the detectors will not be used, generally. The second problem was stated as a recommendation by the Training Committee, "Encourage industry to develop a low-cost flight simulator capable of realistic simulation of turbulence,..." in order that aviation training for general aviation will be more realistic. An alternative to this suggestion is that general aviation pilots be given training or practice in fair weather cumulus. The third problem stated by the Turbulence Committee is, "Another attempt should be made to standardize terminology." Closely related to this terminology problem is that of communication between the various groups serving the aviation industry.

The closing statement of the Summary Report of the Turbulence Committee should give us some encouragement, "It is evident that substantial improvements in all facets of detection, prediction, and communication of turbulence information are on the horizon." Thus, what we need to do is to accelerate our efforts to reach the horizon.

COMMENTS

Three main points emerged at this workshop, which had as its theme the exploration of training and education requirements in the area of aeronautical operations in the natural environment: (1) the need for better and more thorough training, (2) the need for better forecasts and forecast methods, and (3) the need for improvement and standardization of communication. An additional point which came through in more subtle form was that new and/or better detectors (instrumentation) are needed. As a consequence, some thought has been given by the Organization Committee to the possibility of instrumentation needs being the theme or at least a part of the theme for the Fourth Annual Workshop next year.

REFERENCES

Camp, D.W., and Walter Frost (Eds.) 1977: "Proceedings, First Annual Workshop on Meteorological Inputs to Aviation Systems," NASA CP-2028/FAA-RD-77-173, Washington, DC.

Frost, Walter, and D.W. Camp (Eds.) 1978: "Proceedings, Second Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems," NASA CP-2057/FAA-RD-78-99, Washington, DC.

SECTION II

INTRODUCTION AND WELCOME REMARKS







OPENING REMARKS

John H. Enders

NASA Headquarters

On behalf of the Workshop Organizing Committee and NASA's co-sponsoring agencies, FAA and NOAA, welcome to the Third Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems. These workshops provide a unique and much-needed forum for the exchange of ideas and views on various aspects of aviation weather as seen across the extremely broad spectrum of aviation and aviation-related activities.

The First Annual Workshop provided an opportunity for a "mix" of researchers, pilots, designers, forecasters, air traffic and weather service specialists, and airline management to express their individual and collective views on weather problems in the aviation system. The Second Annual Workshop held last year focused on detailed examination of the most severe weather problems identified at the first workshop, with a view towards seeking concensus on appropriate public and private sector actions to solve these problems. Out of those discussions last year it became apparent that training and education throughout the system was important to achieving a better understanding of weather hazards and weather-tolerant designs and operations. This Third Annual Workshop has been organized to explore the training and education questions in more detail in the context of design, operations, and accident investigation.

The outputs of these workshops are considered carefully by the sponsoring agencies, and I can assure you that NASA's aviation meteorology R&D program planning is impacted by the expert concensus obtained from the workshop committees. For example, as a direct outgrowth, we convened a specialists' workshop on icing problems which in turn has resulted in the reestablishment of an Icing Research Group at our Lewis Research Center. We are also placing more emphasis on severe storms research as a result of discussions carried out at these workshops, so you should feel confident that your discussions here will be heeded and that through this mechanism you can have some impact on programs. I am sure that Mr. Sowar and Mr. Connolly could cite similar examples within FAA and NOAA where feedback from these workshops has been reflected in their program planning process.

Some of you have been here before. To you, welcome back; to the newcomers, welcome to what I believe you will find to be a most stimulating and productive two and one half days.

DESCRIPTION OF WORKSHOP

Walter Frost
The University of Tennessee Space Institute

and

Dennis W. Camp
NASA/Marshall Space Flight Center

In keeping with the annual format of the previous Workshops on Meteorological and Environmental Inputs to Aviation Systems, this workshop is again designed to devote a major portion of its time to committee meetings where the maximum exchange of information is achieved through direct communication between people from a number of disciplines in the aviation community. The fixed committees this year are assigned the specific topic areas of Training, Flight Operations, Accident Investigation, Air Traffic Control, and Airports. The floating committees are entitled Winds and Wind Shear; Icing and Frost; Atmospheric Electricity and Lightning; Fog, Visibility and Ceilings; and Turbulence. The theme of this year's workshop is training and communication.

The committees are made up of personnel from many fields related to aviation weather. In attendance are meteorologists, pilots (general aviation, commercial and military), air traffic controllers, accident investigators, scientists, researchers, planners, and educators working in the various areas of aviation systems and meteorology for government agencies, industries and universities. A list of the agencies from which people are in attendance is given in Table 1.

Five overview papers have been invited for this morning session. These invited presentations will be in the form of assertive, informative type papers giving overviews of the areas selected for round table discussions. The papers will acknowledge past work or state of the art, assess past work in view of today's needs, identify needs not satisfied by our current data base, and suggest general options which should be explored but are not specifically product-oriented. Round table discussions will take place following the invited presentations where the five fixed committees will meet separately and sequentially with the five floating committees. The make-up and organization of the committees are described below.

Committees consisting of a chairman and the membership, shown in Table 2, have been assembled to cover specific topics under the general categories. The interaction of the committees will be to address problems pertaining to their topic areas and to recommend actions necessary to effect solutions to these problems. Working sessions where the floating committees meet individually with each of the fixed committees

Table 1

PARTICIPATING AGENCIES

GOVERNMENT AGENCIES (CIVILIAN)

National Aeronautics
and Space Administration

Headquarters
Ames Research Center
Kennedy Space Center
Langley Research Center
Lewis Research Center
Marshall Space Flight Center
Wallops Flight Center

Department of Commerce

National Oceanic
and Atmospheric Administration

- National Weather Service
- Atmospheric Physics and Chemistry Laboratory
- National Severe Storms Laboratory

Department of Transportation

Federal Aviation Administration

- Atlanta ARTCC
- Flight Standard Service
- General Aviation Division
- Jacksonville ARTCC
- National Aviation Facilities Experimental Center
- Systems Research and Development Service

National Transportation Safety Board
Tennessee DOT Bureau of Aeronautics

GOVERNMENT AGENCIES (MILITARY)

United States Air Force

Air Force Fluid Dynamics Laboratory
Air Weather Service
Safety Center
12th Weather Squadron
4950th Test Wing

United States Army

Research and Technology Laboratory

United States Navy

Naval Research Laboratory

COMPANIES

ARAP, Inc.
Boeing Commercial Airplane Company
Bunker Ramo, Inc.
Douglas Aircraft Company
Federal Express Headquarters
FWG Associates, Inc.
System Safety Associates, Ltd.

AIRLINES

Delta Airlines Flight Control
Flying Tiger Line
United Airlines Flight Training Center

AIRPORTS

Los Angeles Department of Airports
Port Columbus International Airport

AGENCIES

Air Line Pilots Association
Air Traffic Controllers Association
Air Transport Association of America
Aircraft Owners and Pilots Association
Professional Air Traffic Control Organization

UNIVERSITIES AND RESEARCH INSTITUTES

Battelle Pacific Northwest Laboratory
Embry Riddle Aeronautical University
South Dakota School of Mines and Technology
St. Cloud State University
University of Dayton
University of Tennessee Space Institute

INTERNATIONAL ORGANIZATIONS

British Meteorological Office
Canadian Atmospheric Environment Service
National Research Council of Canada

Table 2

FIXED COMMITTEES

Training

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John R. Colomy	Director, Aviation Education Resource Center St. Cloud State University St. Cloud, MN 56301 (612)255-3110 or 253-1500
Don S. Cornwall	ALPA 2006 East Mary Creek Pearland, TX 77581 (713)485-1095
William Critch	Flight Training Center Boeing Training Center P.O. Box 3707 Seattle, WA 98124 (206)655-3395
Richard D. Gless	Vice President AOPA Safety Foundation 7315 Wisconsin Avenue Bethesda, MD 20014 (301)951-3961
George R. Hammond	Commander, 12th Weather Squadron Peterson AFB, CO 80912 (303)635-8911 x626
Ralph D. Kimberlin	The University of Tennessee Space Institute Tullahoma, TN 37388 (615)455-0631 x216
Louis Ludwig	FAA/General Aviation Division 800 Independence Avenue SW Washington, DC 20591 (202)426-8196
Loyd C. Parker	NASA Wallops Flight Center Wallops Island, VA 23337 (804)824-3411 x640

Table 2 (cont'd)

FIXED COMMITTEES

Flight Operations

James M. Dunkel, Chairman	Director, Operations Control Federal Express Headquarters AMF Box 30167 Memphis International Airport Memphis, TN 38130 (901)369-3495
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H. Grady Gatlin	Director - Operations Air Transport Association of America 1709 New York Avenue NW Washington, DC 20006 (202)872-4015
Dale Istwan	ALPA 11534 Corlyn Drive St. Louis, MO 63138 (314)741-9259
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Table 2 (Cont'd)

FIXED COMMITTEES

Accident Investigation

Charles L. Pocock, Chairman	Chief, Bomber and Transport Branch USAF Safety Center Norton AFB, CA 92409 (714)382-2226
Alan I. Brunstein	Chief, International Liaison National Transportation Safety Board Washington, DC 20594 (202)472-6143
Peter Chesney	Accident Investigation Staff FAA Flight Standard Service AFS-50 800 Independence Avenue SW Washington, DC 20591 (202)426-3120
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Russell S. Lawton	Director, Operations and Safety AOPA 7315 Wisconsin Avenue Washington, DC 20014 (301)951-3910
William Melvin	ALPA 1101 West Morton Denison, TX 75020 (214)463-1246
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Andy D. Yates, Jr.	ALPA 7413 Park Terrace Drive Alexandria, VA 22307 (703)765-7423

Table 2 (Cont'd)

FIXED COMMITTEES

Air Traffic Control

Frederick M. Stone, Chairman	HQ AFCS/USAF Air Traffic Control Scott AFB, IL 62269 (618)638-5462
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James R. Banks	President - ATCA 881 Vassar Drive Edwardsville, IL 62025 (618)256-3174
C. L. Chandler	Manager, Weather Delta Airlines Flight Control Atlanta International Airport Atlanta, GA 30320 (404)346-6478
A. Charley McTee	Human Factors Program Manager Bunker Ramo Box 2696 Universal City, TX 78148 (512)658-5493
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W. Don Wood	Chief, Atlanta Air Route Traffic Control Center 299 Woolsey Road Hampton, GA 30228 (404)946-3511

Table 2 (Cont'd)

FIXED COMMITTEES

Airports

William J. Hall, Chairman	Tennessee Bureau of Aeronautics P.O. Box 17326 Nashville, TN 37217 (615)741-3208
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Daniel F. Ginty	Airport Manager Port Columbus International Airport 4600 East 17th Avenue Columbus, OH 43219
Loyd C. Parker	NASA Wallops Flight Center Wallops Island, VA 23337 (804)824-3411 x640
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Joseph M. Schwind	ALPA 1625 Massachusetts Avenue Washington, DC 20036 (202)797-4188
Tom Yager	MS 497 NASA Langley Research Center Hampton, VA 23665

Table 2 (Cont'd)

FLOATING COMMITTEES

Winds and Wind Shear

Thomas P. Incrocci, Chairman	Chief, Forecast Methods & Materials HQS AWS/DNTM Scott AFB, IL 62225 (618)256-4624 or 256-4850
Fernando Caracena	NOAA-ERL-APCL R-31 Boulder, CO 80302 (303)499-1000 x6269
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Norman L. Crabill	MS 247 NASA Langley Research Center Hampton, VA 23665 (804)827-3274
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Sepp J. Froeschl	Canadian Atmospheric Environment Service 100 Alexis Nihon Blvd. Ville St. Laurent, Quebec H4M-2N8 Canada (514)333-3070
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Table 2 (Cont'd)

FLOATING COMMITTEES

Icing and Frost

James K. Luers, Chairman	University of Dayton Research Institute 300 College Park Drive Dayton, OH 45469 (513)229-3921
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Table 2 (Cont'd)

FLOATING COMMITTEES

Atmospheric Electricity and Lightning

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Greg von Bokern	Boeing Company MS 47-47 P.O. Box 3707 Seattle, WA 98124 (206)655-8408
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Kirk E. Lehneis	AWS/DNTS Scott AFB, IL 62225 (618)256-4741
Charles F. Schafer	ES-82 NASA Marshall Space Flight Center AL 35812 (205)453-1886

Table 2 (Cont'd)

FLOATING COMMITTEES

Fog, Visibility and Ceilings

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James T. Bradley	NOAA/NWS/Test and Evaluation Division RD 1, Box 105 Sterling, VA 22170 (703)471-5302
Larry S. Christensen	FWG Associates, Inc. RR2, Box 271-A Tullahoma, TN 37388 (615)455-1982
Walter V. Collins	Director - Noise Abatement Los Angeles Dept. of Airports 1 World Way Los Angeles, CA 90009 (213)646-9410
Roger G. Flynn	209 North Water Street Chestertown, MD 21620 (301)778-1077
Ronald H. Kohl	The University of Tennessee Space Institute Tullahoma, TN 37388 (615)455-0631 x334
Otha H. Vaughan, Jr.	ES-83 NASA Marshall Space Flight Center AL 35812 (205)453-5218

Table 2 (Cont'd)

FLOATING COMMITTEES

Turbulence

R. Craig Goff, Chairman	FAA/NAFEC ANA-410, Building 10 Atlantic City, NJ 08405 (609)641-8200 x2257
James W. Bilbro	EC-32 NASA Marshall Space Flight Center AL 35812 (205)453-1597
James E. Dieudonne	MS 125B NASA Langley Research Center Hampton, VA 23665 (804)838-3823
John C. Houbolt	MS 116 NASA Langley Research Center Hampton, VA 23665 (804)827-3285
John Keller	University of Dayton 300 College Park Drive Dayton, OH 45469 (513)229-3921
Peter M. Kuhn	Project Leader, Infrared Remote Sensing NOAA/APCL Boulder, CO 80302 (303)499-1000 x6208
W. Steve Lewellan	ARAP, Inc. Box 2229 Princeton, NJ 08540 (609)452-2950
William T. Pennell	Battelle Pacific Northwest Labs Box 999 Richland, WA 99352 (509)942-4620
John Prodan	Institute of Atmospheric Sciences S. Dakota School of Mines and Technology Rapid City, SD 57701 (605)394-2291
Richard H. Rhyne	NASA Langley Research Center Hampton, VA 23665 (804)827-2273

will be conducted and the outcome and conclusion of the meeting recorded. The committee chairman will then be responsible for writing a final committee report for documentation of the workshop, in a proceeding which will be published. These write-ups will assess the problems as to range, scope and information transferral. For example, the results of the round table discussions should yield information pertaining to (1) needs, (2) present knowledge, (3) current methods, and (4) information exchange possible between agencies.

The third day will be a plenary session consisting mainly of the chairmen's presentations of overviews of their committees' discussions and outlines of their intended write-ups. General comments and recommendations from the entire group will be called for during this final session.

WELCOME REMARKS

Charles A. Lundquist

NASA Marshall Space Flight Center

The agenda for this workshop conveys the clear recognition that environmental inputs for aeronautical operations require a broad interdisciplinary treatment. Likewise, the diverse interests and specialities represented by the workshop participants reflect the same message. The organizers of this gathering expect that its productivity will be enhanced by the planned interdisciplinary treatment.

A multidisciplinary effort, such as that embraced in the scope of this workshop, highlights the communications problems that too often exist between diverse interests and responsibilities. Communications issues are therefore given particular attention in the agenda. In this vein, the workshop organizers believe that individual participants will appreciate and benefit from the opportunity to exchange ideas with colleagues from related fields.

I should like to emphasize that we at the Marshall Space Flight Center take seriously the "Aeronautics" in our agency name. We find that the topics of rocketry and aircraft flight through the atmosphere require the same knowledge of atmospheric phenomena. With technological advancement, these topics merge even more intimately. The Space Shuttle, for example, flies out of the atmosphere much as a traditional rocket craft. However, it returns through the atmosphere and lands on an airstrip as a nearly conventional aircraft.

Certainly we hope and trust that the ambitious objectives of this workshop are in consort with the pressing needs of the aeronautical community and with the desire of NASA to address these needs.

WELCOME REMARKS

Robert L. Young

The University of Tennessee Space Institute

On behalf of Dr. Edward Boling, President of The University of Tennessee, and Dr. Charles Weaver, Vice President of the University and Dean of the Space Institute, it is my pleasure to welcome you. We are very pleased with Dr. Frost's Atmospheric Science Division and the many good things that have come from his concept of meteorology with a strong emphasis on engineering. We are grateful for your attendance at this Third Annual Workshop featuring meteorology, the environment, aviation and engineering. The support of NASA, NOAA and FAA is much appreciated. Since its inception in 1964, the Space Institute has defined space as beginning at ground level and continuing upward indefinitely. Through this workshop and several activities we strive to make contributions to aviation. Our efforts include graduate level academic and research work in areas important to aviation progress, a short course program which features intensive instruction in many theoretical and applied areas pertinent to aviation, and two well-instrumented aircraft for instruction and research in airplane performance, stability, control and handling qualities, Figures 1 and 2. We have just obtained a novel, blown-wing aircraft (Figure 3) which promises to give our faculty pilots and graduate students much entertaining research. In the near future, we are anxious to expand our activities in avionics.

So, our best wishes for a third successful meteorology/environment/aviation workshop. Let us do anything we may to make your stay here pleasant and productive.



FIGURE 1. DEHAVILLAND OTTER.



FIGURE 2. CESSNA-310.



FIGURE 3. BALL-BARTOE JETWING.

SECTION III

TOPIC AREA

PRESENTATIONS









METEOROLOGICAL INPUT TO GENERAL AVIATION PILOT TRAINING

John R. Colomy

St. Cloud State University

Analyzing meteorological input to general aviation pilot training programs requires an examination of the present effectiveness of the meteorological education process and the examination of the instructor's preparation, the "symbol set" utilized in the communication, and the student's experience in meteorology. Specific recommendations may then be presented based upon the analysis.

In order to be a safe and proficient pilot one must develop effective, cognitive, and psychomotor data in the "human computer" through education. Persons may be very knowledgeable about the factors that affect flight operation, but without experience in the skills involved this author would seriously doubt their ability to operate the system. On the other hand, an individual may be "God's gift to aviation" in skill, but without a knowledge of procedures, meteorology, systems design, and performance parameters, this author would doubt if they would be safe pilots. Knowledge and skill are equal requirements for safe and proficient pilot operation.

One may evaluate, to some extent, our present educational effectiveness by examining the statistics of those individuals who have not been successful in avoiding difficulties (i.e., weather-related accidents). One must realize that these statistics do not reflect those individuals who have survived a "close encounter of the terrifying kind" with a resolve to never again attempt a flight in that type of meteorological phenomena.

The Annual Review of Aircraft Accident Data for the general aviation calendar year 1977, published by the National Transportation Safety Board, indicates a total accident count for 1976 of 4,193 and a total accident count for 1977 of 4,286. Of 1,490 accidents involving injury, 239 occurred in weather that was below minimums. There was a total of 317 accidents in IFR weather and 27 in weather that was below minimums. The total accidents involving small fixed-wing aircraft were 3,842 with 875 involving weather as a cause or factor in the accident. Weather was involved in 22.7% of the reported small fixed-wing accidents. The latest specific information available on weather-related accidents is for 1976 in *Brief of Fatal Accidents Involving Weather as a Cause/Factor*, published by the National Transportation Safety Board. The report indicates a decrease in the weather-related accidents per hours flown since 1967, but also indicates 908 accidents involving

weather in 1976. The briefs presented on weather-related accidents indicate that many pilots had failed to maintain aircraft control. Weather did not directly cause these accidents; pilot disorientation was the cause. The disorientation was induced by lack of visual reference and not necessarily by the severity of the weather. The lack of pilot understanding of the effects of meteorological phenomena on pilot operation is evident.

The indications are that the meteorological input into general aviation pilot training programs should, indeed must, be improved. In order to arrive at a practical set of recommendations, the present "system" must be evaluated.

The "FAA approved" definition of learning is a "change in behavior brought about through experience." This author would add to this definition that the experience may be real or imagined. Most educators mix the real and imagined experiences for their students. Some disciplines do not lend themselves to the use of real experience in the educational process and there may be other restrictions (staff, facilities, budgets) that prohibit the educator from involving the student in a real experience during the educational process. This does not indicate, however, that the learning experience was not a valuable one for the student if the imagined experience was a well-contrived one. I think that one would agree that the emotional experience one had during the viewing of Alfred Hitchcock's *Psycho* was indeed a very "real" one. In recent years the industry has utilized aircraft simulators as a means of substituting imagined experience for real experience and this has proved to be most effective.

Education has many objectives to include: the discovery of new knowledge, the dissemination of existing knowledge, and the translation of facts and knowledge into action on the part of the student. Meteorological research involves the utilization of technology to expand our knowledge of the ongoing process. The specifics of the meteorological education system that this paper examines involve the dissemination and translation phases of the process.

Meteorological education is a communications system involving a sender (educator), a set of symbols (vehicle), and a receiver (student). It is vital to the effectiveness of the individual's education that the system maintains its integrity. Each "block" is vital to the structure of the system. Education is a lifelong process and, therefore, one must not restrict the examination of meteorological education to the initial "precertification" classroom phases of pilot training.

Professionalism is a must for the educator to be effective. This applies to all meteorological instructors, be they classroom teachers, flight or ground instructors, or pilot briefers. Professionalism requires extended training and preparation; study and research; logical and accurate thinking; good judgment; and, perhaps most important, individual commitment to become the best that one is capable of becoming while operating within the system.

The general aviation industry is confronted with several problem areas concerning flight and ground instruction in general and in meteorological education specifically. Historically the training and preparation of a pilot to become an instructor has been minimal. Very few flight and ground instructors have received an education in the teaching process similar to that which is required for teacher certification of elementary or secondary educators. The recertification requirements are minimal compared with the ongoing education that is required of an instructor in a school system. The typical exposure to the theory of education involves a memorization of the *Flight Instructor's Handbook* in order to pass the FAA *Fundamentals of Instruction* written examination. The applicant may receive some classroom or individualized instruction in the educational process, but this is usually conducted by another instructor who was trained using the same approach. The result has been a minimal knowledge of the educational process among the majority of flight and ground instructors.

The problem is compounded by the specific background in various disciplines that is required for competent instruction. The meteorological background of most instructors is limited to the exposure during initial pilot certification (i.e., the meteorological sections of the private and instrument courses). This background varies from "reading the chapter" to instruction received from another pilot who is a product of the same system. Few pilots are fortunate enough to have received instruction, in depth, from professional meteorologists or individuals with extensive education in this area. Continuing education in meteorology is not a requirement for the typical flight or ground instructor.

Another area of concern is the transitory nature of the majority of general aviation instructors. Many individuals who seek certification are utilizing the instructor position as a bridge to a career in corporate or airline operation. This is not to say that these individuals are inadequate instructors, but to indicate that the cadre does not have an average experience level that is found in the secondary school system, for example. Unfortunately, many of these individuals are more interested in building time than they are in teaching technique or study and research in the required disciplines. They, in many cases, are not interested in becoming the best instructors that they are capable of becoming while they are involved in flight instruction.

The recent increase in airline flight crew positions has depleted the military, corporate, and general aviation pool of pilots. There is currently a shortage of flight instructors in many parts of the country. More individuals are leaving the profession than are entering it, primarily because of economics (i.e., income). The positive aspect of this shortage will be an increase in the average income of a general aviation instructor, which, most individuals feel, is long overdue.

There is also a problem area in instructor education that relates to quality control. School teachers must complete a period of time in a practice teaching situation for certification before graduation. There is no such provision for the general aviation instructor. The practice teaching experience involved in instructor training is usually limited to the student instructor practicing presentations to the instructing instructor. The student instructor usually has no opportunity for a real experience of teaching students under supervision. Evaluation of an applicant's instructing ability is limited to the certification practical examination, which is a minimal look at the applicant at best.

Those individuals that educate the general aviation pilot in the present and future trends of the meteorological system (i.e., meteorologists and Flight Service Station briefers) are critical to general aviation operations. These educators must also have extensive preparation, training, and continuing education. The fact that it is possible to obtain two different briefings from two different briefers at the same Flight Service Station within a short time frame is an indication that the briefer's education should be examined.

The sender of communications must be knowledgeable of the receiver's background in order to establish a set of symbols to be utilized in the process. It is obvious that there is a necessity to utilize a set of symbols in this communication that have the same meaning to the receiver as they do to the sender. This "symbol set" is critical to the educator (teacher and briefer) if he is going to be effective while painting a weather picture for the student or pilot. The term "bumper" may be received as meaning a thunderstorm or as meaning the device found on the front and back of an automobile, for example.

An examination of the present symbol set reveals a mixing of meanings and symbols that are difficult to learn, easily forgotten and easily misunderstood. The sequence report utilizes some numbers to represent statute miles (visibility), some numbers to represent nautical miles (wind velocity), and some numbers to represent feet (RVR values). The terminal forecast will omit a visibility number if the forecast is for visibility greater than six miles and will omit a wind group if the forecast winds are less than 10 knots. The area forecast does not utilize the same format as the terminal forecast, but is prepared in a "notehand" presentation utilizing contractions.

The weather charts utilize different presentations depending upon the type of chart or the level it represents. The lines utilized on a surface analysis chart represent isobars, the lines on a weather depiction chart represent restrictions to visibility or ceiling, and the lines on a radar summary chart represent areas of radar echo return. The lines on a low level significant weather prognostic chart are utilized to represent ceiling and visibility restrictions, freezing levels, turbulence areas, and isobars. The high level significant weather prognostic charts illustrate surface locations of pressure centers and

fronts, but present cloud cover only above 24,000 feet MSL (400 millibars). The cloud cover is described with numbers representing eighths of coverage instead of the surface chart symbol which represents tenths of coverage. The constant pressure charts may or may not present temperature-dew point spread, or isotachs, depending upon the level represented. The contour levels vary and the height is presented in meters.

The term "VFR" (Visual Flight Rules) may indicate visibility is greater than five miles and ceiling is greater than 3,000 feet when used in a forecast. VFR may also indicate a visibility range of one to five miles depending upon altitude and type of airspace when used in reference to the Federal Aviation Regulations.

The difficulties encountered by educators and students alike in mastering the symbol set are compounded by the dissemination of the communications. Recent budget reductions have eliminated some offices of the National Weather Service and curtailed staffing at others. Flight Service Stations have also received budget cutbacks. The pilot, in many locations, does not have ready access to the meteorological communications system, much less the opportunity for an in-person briefing.

There are several facets to the receiver's (student's) perception of a communication: physical organism, basic need, goals and values, self concept, time and opportunity, and recognition of the element of threat. One of the most important factors is motivation. Does the meteorological communication system positively motivate the student to learn? Does the system create the desire to learn about meteorology or does it force the student to learn only what is necessary to pass a written examination?

This author questions the effectiveness of the experience in meteorology that is currently available in general aviation pilot training programs. It is possible for a pilot to be certificated without any experience in low ceiling or low visibility operations. The regulations, however, then allow that individual to carry passengers in as low a visibility as one mile while only remaining clear of clouds. Pilots may receive the instrument rating without ever making a flight into a cloud or storm system. How does one understand the effects of structural ice accumulation and other conditions without experience? Simulator technology is providing the student with the opportunity to experience a "real" contrived situation, but is not currently available to the general aviation pilot.

Is there a need to change the meteorological communication system? This author belives that change for improvement is feasible and necessary.

Historically, most flight and ground instructors in general aviation came from the pilot ranks. They were pilots first and through a

minimal amount of training became instructors. Perhaps the industry should encourage universities to develop a professional aviation instructor curriculum that would parallel those curricula currently used to educate secondary school teachers. This would take those individuals that are by nature teachers and educate them in aviation. This would provide the industry with a stable cadre of professional educators that are well educated in teaching techniques as well as in the disciplines of aviation. Advanced coursework in meteorology could be a graduation requirement. In addition, a practice teaching experience requirement would provide the student instructors with "real" teaching experiences and an evaluation of their knowledge and teaching technique.

An FAA regulatory change requiring newly certified instructors to teach under the supervision of selected chief flight instructors for the first year might also be appropriate. The senior instructor would assist the new teachers in their flight and ground instruction, evaluate the new instructor's students, and make recommendations for permanent certification.

The symbol set utilized in meteorological communication should be reevaluated by NOAA and educators to improve the consistency of meaning of the symbols utilized. The objective is to communicate and not to confuse. A consistent set of symbols would assist the educator (teacher and briefer) and replace confusion with understanding on the part of the student.

New methods of communication dispersal utilizing today's technology must be developed. The use of computer-stored cathode ray tube displayed data should be expanded. The development of higher resolution pictures and an improved dispersal system for them should be pursued.

Educators must develop a meteorological presentation that positively motivates a student to learn. Instead of presenting the material in such a way that implies memorization to pass a test, the "senders" should attempt to develop a desire to learn on the part of the "receivers."

This author believes that much can be done to improve the meteorological experience the current system provides. The use of CRT displays incorporating computer-generated visual references on general aviation simulators should be developed. These displays have the capability of depicting various visibility and ceiling conditions and would provide the student with the experience in operation during marginal weather.

Video tape programs depicting in-flight meteorological encounters would be valuable in teaching what flight under various situations is like. It is difficult to teach what a flight in or around a well-developed thunderstorm is like. It is difficult to teach the "pilot

terror" developed when encountering moderate ice in an aircraft not equipped with deice systems. Well-structured video programs incorporating pilot comments could be very effective.

Flight instructors should also attempt to provide real experience in flight operation during low ceilings or visibilities. One does not have to operate in a thunderstorm to receive an impression of the energy involved. Certainly every pilot who receives an instrument rating should have some experience in real instrument flight.

Can the system be improved? Yes. Will improvement in the meteorological education system improve flying safety? Yes. It is the responsibility of the system managers to seek the necessary improvements. It will benefit all.

NEEDED WEATHER INFORMATION WHERE IT BELONGS--IN THE COCKPIT

H. Grady Gatlin

Air Transport Association of America

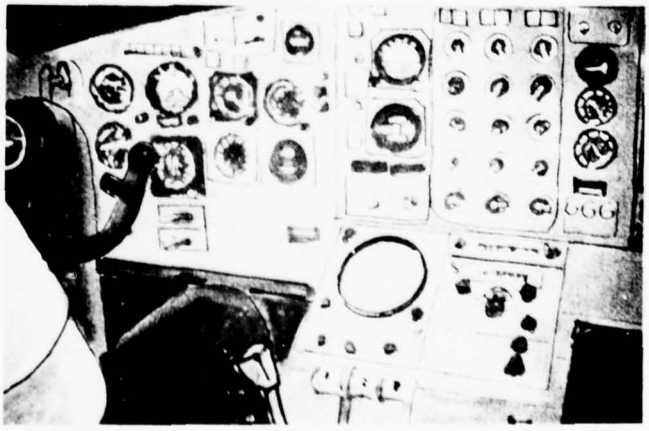
Mr. Gatlin's presentation began with an illustrative slide show emphasizing the sudden and unexpected severe weather encounter. The editors have attempted to reproduce this in print for the benefit of the reader.

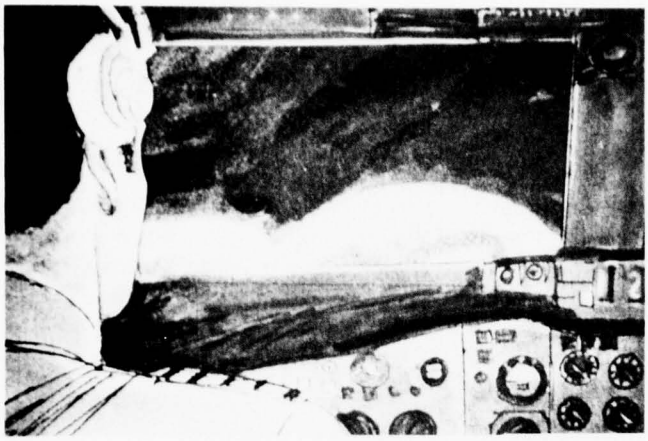
Jet engine sounds begin.



Captain: "There wasn't any weather like this in the forecast!"

First Officer: "This radar's not painting a very good picture--the controller doesn't have it either!"

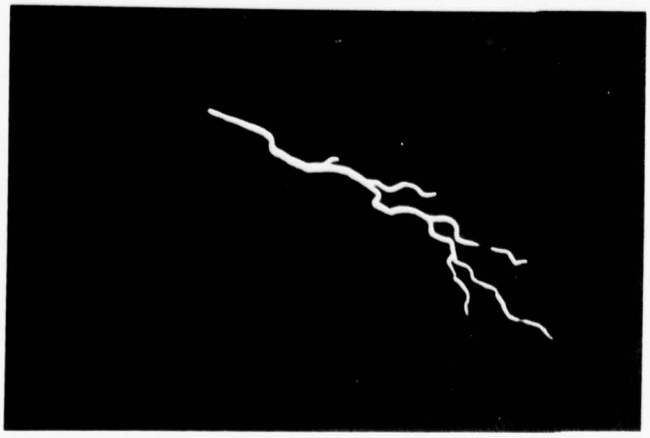




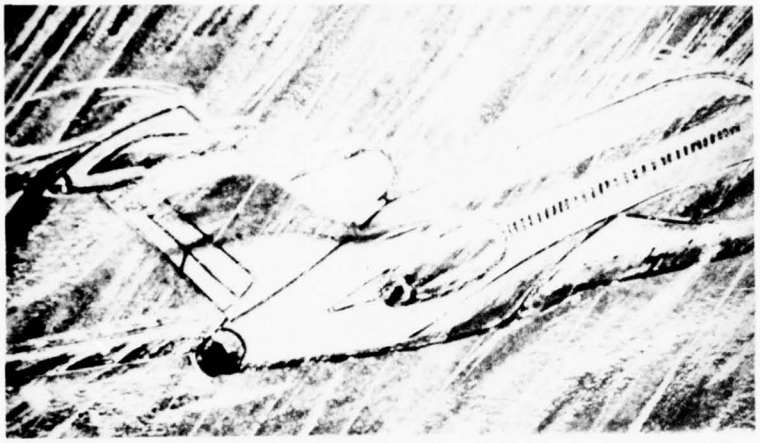
Captain: "We're going to have to go right through..."

First Officer: "It looks better there--let's try it!"





Small lightning flash.



Thunder sound over engine noise.

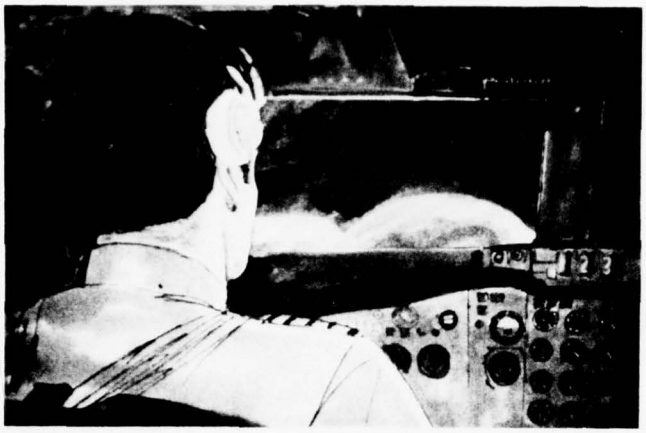
Rain noise on metal.

First Officer:
"There's the rain!"





Engine sound loud as scene goes to exterior of airplane.



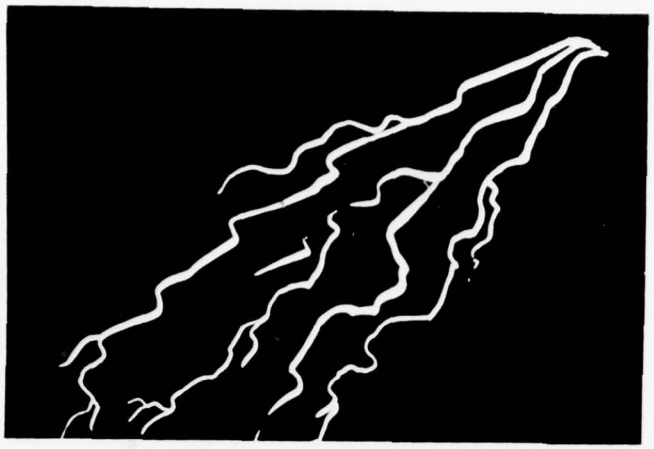
Captain: "That's hail now!"

Thunder.





Sounds lessen.



Big lightning flash.

Loud thunder.

Thunder rolling, then silence.



I assume every pilot has had a similar experience and wondered, "How in the hell did I get into a situation like this!"

Or perhaps he has been unfortunate enough to be involved in weather-related accident investigations attributed to wind shear, turbulence, or other hazardous weather conditions--accidents that might have been avoided if the pilot had had needed weather information where it belongs--in the cockpit. So as the Flight Operations overview for this workshop let's look at "Needed Weather Information Where It Belongs--In the Cockpit."

But who says we need any information in the cockpit anyway? Well, for one, the FAA! They proposed a rule in 1976 which was adopted and implemented on December 31, 1977, which says, in effect, "all available weather reports and forecasts of weather phenomena that may affect the safety of flight, such as clear air turbulence, thunderstorms and low altitude wind shear for each route to be flown and airport to be used" must be provided to the pilot-in-command by the airline dispatchers before and during each flight.

Even without the regulations, however, the number of weather-related accidents in the industry testifies to the need for accurate real-time weather being available to the pilot--66 at JFK; New Hope, Georgia; St. Louis; Fiji; etc. All too often the information in the system never reaches the cockpit where it's needed.

The FAA categorizes weather as hazardous when it is dangerous to aircraft, passengers, and crew and is generally associated with:

- Thunderstorms
- Turbulence (clear air--mountain waves)
- Icing
- Wind shear
- Ceiling and visibility (deteriorating)
- Wind (sustained 30 knots or greater)

Routine weather is categorized as:

- Air temperature
- Dew point
- Atmospheric pressure
- Cloud height and cover
- Wind direction and velocity
- Peak gusts
- RVR
- Precipitation
- Altimeter settings
- Winds and temperatures aloft

To comply with the FAR's, a pilot as stated must be provided with available hazardous and routine weather information before and during flight to permit planning and execution in a safe and efficient manner, and the airline dispatcher (even many, many miles away) is to furnish it.

Today, the airlines' means of providing weather information to the pilot is involved with computerized flight plans and weather packages. As an example, one of our major airlines has a direct communications link between the FAA Weather Message Switching Center in Kansas City and the airline's reservations computer. Weather information is stored in the computer and is available for immediate display and/or reproduction to Dispatch, Meteorology, and any other location having a CRT or a direct

link to its central computers. In addition, another direct link from the National Meteorological Center at Suitland, Maryland, provides wind and temperature aloft forecasts.

This stored information is used to provide Flight Dispatch a computerized flight plan along the FAA preferential route before the crew arrives at the airport, and if the preferential route is longer by six minutes or more, another minimum route or minimum cost plan will automatically be provided.

On his arrival, the pilot reviews posted weather information that contains past, present, and forecast weather conditions. But more importantly, attached to his flight plan for review and use will be a computerized weather package. This package is sometimes called "The Command Weather Document." This document is specifically tailored for each flight, providing NOTAMS, field conditions, hourly sequences and forecasts for that particular route, thereby eliminating all extraneous information. It is possible, however, for the pilot to request additional weather on the CRT or hard-copy printouts. It is also possible and desirable for the pilot to receive verbal briefings from the dispatchers or meteorologists when weather conditions call for it.

At this point the pilot has been given access to all the available weather information in the system and should be able to conduct a safe flight insofar as weather is concerned. Perhaps we should take a closer look at where all this information comes from, how it was collected and distributed, and whether it is currently valid concerning flight safety.

The current Aviation Weather System is a collection of functionally independent elements employing primarily a slow (100 WPM) and medium (1200 WPM) speed teleprinter distribution network coupled with a slow-speed electrowriter system which is used to transmit both weather and airport data. Basically, the system can be considered slow, labor intensive, and not capable of meeting the demand for timely and accurate weather information needed by the airlines to operate in the National Airspace System. As an aside comment at this time, it should be pointed out that the airlines are closely following developments and planned implementation dates of the Automation of Field Observations and Services (AFOS) Program by the National Weather Service, which will provide the graphic forms via CRT. However, cost of installation, equipment, and needed change-over circuitry are only a few examples of a myriad of questions to which airlines must have an answer before adopting a position for or against AFOS. As of now, airlines are working closely with segments of NWS in order to ascertain firm dates for reduction of some of the current facsimile circuits known more familiarly as Forecast Office Facsimile (FOFAX) and National and Aviation Meteorological Facsimile Network (NAMFAX). Additionally, it is of paramount importance that information be made available on NWS means to meet stated airline requirements for receipt of weather data from the satellites.

Returning to the real world of today, meteorological data is collected by the National Weather Service, Federal Aviation Administration, Department of Defense, air carriers, and contract observers; and this data includes surface observations, upper air soundings, and radar. The FAA is responsible for 35% of this information as well as the distribution of PIREPS while the National Environmental Satellite Service is the source of all available satellite weather information.

After all this data has been processed through the National Meteorological Center and the Air Force Global Weather Central, it is distributed to the users by the FAA through the Weather Message Switching Center and by the National Weather Service using facsimile for graphic weather information.

This system is time consuming, and although it fulfills the FAR requirements, it does not adequately contribute to safety of flight from hazardous weather conditions. In fact, since upper air data are collected only every 12 hours, the inadequate number of observations leads to errors in the winds aloft forecasts used for flight planning and consequently to less than optimum fuel consumption.

After takeoff, airborne radar weather reports from other flights and air traffic control become the prime source of weather information en route and during approach and final landing. Unfortunately, controllers in the Air Route Traffic Control Centers (ARTCC's) and approach control obtain their weather information from the same source as the airlines, which is not timely enough for real-time decision making by the pilot or controller. In an effort to help decrease the time between when the hazardous weather conditions are observed and when they are received by the pilot of the aircraft concerned, the FAA, in collaboration with the NWS, activated Center Weather Service Units (CWSU) at 13 ARTCC's throughout the country during late 1977 and early 1978. Additionally, the NWS instituted the Convective SIGMET program with FAA broadcasting Convective SIGMET information over its Visual Omni Range/Transcribed Weather Broadcasts (VOR/TWEB) outlets. During the initial testing of the Convective SIGMET program it became apparent to the airlines that the requirement to plot locations of data on significant weather on charts within the cockpit was both burdensome and time consuming and still was not close enough to real time to be useful. Subsequently, following meetings with ATA, airlines, and other segments of industry, NWS and FAA have revised the program, thus eliminating the detailed cockpit plotting requirement specified earlier. We are watching closely both the CWSU and the Convective SIGMET programs.

PIREP's are a source of real-time hazardous weather conditions. Since hazardous weather is subject to rapid change, immediate dissemination of PIREP's is an absolute necessity; however, the majority are not transmitted beyond the receiving facility, and those that are transmitted take so long over the antiquated communications system that they are of no value to the user.

Since airport and air route surveillance radar are optimized for aircraft detection and have limited capability to detect and display storm intensity variations, it does not provide accurate or sufficient definition of weather areas for controllers to provide reliable vectoring or advisory services to the pilots.

The National Weather Service operates a network of weather radar stations east of the Rockies to detect and observe severe weather. They are not collocated with FAA radars and except for special projects are not remoted to FAA ATC facilities. Data from weather radars is used by the National Severe Weather Forecast Center in Kansas City where a radar summary chart is constructed and transmitted by facsimile. Again, this valuable information is not available to the pilots for real-time decision making.

In fact, the only real-time information available to the cockpit is from the FAA control towers which provide wind, altimeter settings and RVR on final approach. Even the Automated Terminal Information Service (ATIS) is subject to providing obsolete information when controllers' workloads are heavy and weather conditions are changing rapidly.

What weather information is needed in the cockpit? In flight planning we need current winds aloft. Observations every 12 hours are inadequate; we suggest that such observations should be made every six hours.

En route and in the terminal areas the pilot needs real-time hazardous weather information and he needs it directly from the observers.

As discussed, the current Aviation Weather System has the information, but it is not available in the cockpit on a real-time basis.

Currently the FAA has developed an Aviation Weather System Preliminary Program Plan designed to improve their capability for providing hazardous and routine weather information to pilots and controllers. The plan is very comprehensive and the FAA should be complimented for its thoroughness. It identifies the problems and proposes solutions, and when it is implemented our Aviation Weather System will have efficient air operations. For this reason we wholeheartedly support this program and all the technological improvements in the plan with one exception. Although the technological capability will be available, the plan is in the future and we need something now, particularly real-time hazardous weather information in the cockpit.

As long as the flight dispatcher is held responsible for providing en route hazardous weather to the pilot and until the FAA assumes some responsibility for real-time information to the cockpit, all the programs, technological improvements, and money spent will not achieve their full potential in providing safe transportation to the traveling public!

Before I close I want to mention my indebtedness to Captain J. E. Frankum, Vice President - Flight Operations, Trans World Airlines for some of the material I have used and for his assistance in this preparation.

ACCIDENT INVESTIGATION

Alan I. Brunstein

National Transportation Safety Board

The National Transportation Safety Board (NTSB) was created by the Department of Transportation Act of 1966, which simultaneously established the Department of Transportation. However, it was the Independent Safety Board Act of 1974 which established the Safety Board as an entirely independent Federal agency and broadened the responsibilities of the Board in the investigation and prevention of transportation accidents. Among other things, the Board is charged with:

- Investigating certain aviation, highway, railroad, pipeline, and marine accidents.
- Reporting publicly on the facts, conditions and circumstances and the cause(s) or probable cause(s) of such accidents.
- Issuing periodic reports to the Congress and to federal, state, and local transportation safety agencies and others recommending measures to reduce the likelihood of transportation accidents.
- Initiating and conducting special transportation safety studies and investigations.

Inasmuch as this workshop deals with aviation systems and the meteorological and environmental inputs to such systems, this overview will deal only with aviation accident investigation and particularly with those cases in which there was a weather involvement. A weather-involved accident will be defined as one in which the Board has determined that weather was a cause or a contributing factor.

Before discussing some specifics of weather-involved accidents it might be appropriate to provide a brief summary of the manner in which the Board conducts its investigations, for the benefit of those attendees fortunate enough not to have been active participants in such investigations. The Board's headquarters are located at 800 Independence Avenue Southwest in Washington, DC,--the same building that houses the Federal Aviation Administration (FAA) headquarters. There are 12 field offices spread out from Miami, Florida, to Anchorage, Alaska. Eleven of those 12 are designated as Aviation Field Offices. Eight of the 12 are also Railroad Offices, four are also Highway Offices and three are also Pipeline Offices, since the Board's work is intermodal. Under normal circumstances, the field offices conduct investigations of general aviation type accidents. The investigation

is usually conducted by one investigator from a field office assisted generally by an FAA man and on occasion by a manufacturer's representative, i.e., the manufacturer of the aircraft, powerplant or on-board systems. The field offices are provided with any required technical backup from appropriate professional experts in Washington. For example, the case may require the services of our metallurgical laboratory, or investigative assistance from an air traffic control specialist, a meteorologist or others. Field office personnel are also called upon to "stake down" the scene of an air carrier accident until an investigative team arrives from Washington, assist in the investigation and also provide logistical support.

Air carrier accident investigations, on the other hand, are conducted differently. In Washington, there is always a so-called "Go-Team" on standby. The Go-Team is made up of about 10 investigators. There is an Investigator-in-Charge and experts in the various technical areas such as operations, air traffic control, weather, powerplants, etc. The team is normally accompanied to the accident scene by a Board Member and a representative from our Office of Public Affairs. In order to develop a complete factual record, the Board will, at an organization meeting, designate Parties to the Investigation to assist the Board in its work. The Parties consist of such agencies as: the FAA, National Weather Service (NWS), local governmental organizations and others. Also included as Parties will be such organizations as: the air carrier involved, airframe, powerplant and systems manufacturers, the Air Line Pilots Association (ALPA), Professional Air Traffic Controllers Organization (PATCO), and various other trade unions and organizations as may be appropriate.

Under the overall direction of the NTSB Investigator-in-Charge the investigation is conducted by the various groups in their own areas of expertise under the chairmanship of an NTSB investigator. Information is exchanged between participants and coordination is effected at periodic Progress Meetings convened by the Investigator-in-Charge. Under the direction of each NTSB Group Chairman, one set of group notes is maintained from which there eventually will be drafted a Group Chairman's Factual Report.

Should circumstances dictate that after the field phase of the investigation is complete a public hearing be held, all Parties are notified and Parties to the Hearing will be designated, normally from among those agencies and organizations which have already participated in the field phase. At the Public Hearing, testimony is taken under oath from appropriate witnesses with questions first from the Board's Technical Panel, normally made up of NTSB Group Chairmen. Questions are also allowed from spokesmen from each of the designated Parties as well as from members of the NTSB Board of Inquiry which conducts the hearing. Subsequently, a formal Board report will be prepared for public release and will contain pertinent findings and the cause or probable cause. At any time after the accident, the Board could issue Safety Recommendations pertinent to the case involved, directed to

appropriate agencies and organizations with an indication of the priority status of each recommendation. Also, as you know, the Board does periodically publish reports on special studies it has developed on various subjects. We are aware that previous workshops discussed at some length the results of the Board's Special Study on Fatal Weather-Involved General Aviation Accidents.

Most of the remainder of this overview paper will be divided into two categories, i.e., information concerning air carrier accidents and information relating to general aviation accidents.

General Aviation Accidents

Table 1 has been developed to provide an overview of all general aviation accidents over a recent 5-year period as well as a comparison between all accidents and the weather-involved accidents. The NTSB continues to be concerned not only with the overall accident picture, but with the continuing large number of weather involvements. Weather continues to be one of the most, if not the most frequently cited causal factor in fatal, general aviation accidents. Table 1 shows that 16.5% of all accidents are fatal, that 22.4% of all accidents are weather-involved, and that 38.6% of the fatal accidents are weather-involved accidents. Looking at just the weather-involved accidents, more than 28% of those are fatal, and, on the average, two or more people are killed in each one.

Table 1

U.S. GENERAL AVIATION ACCIDENTS

	All Accidents			Weather-Involved Accidents		
	Total	Total Fatal	Fatalities	Total	Total Fatal	Fatalities
1973	4,255	723	1,412	963	273	618
1974	4,425	729	1,438	1,009	300	702
1975	4,237	675	1,345	985	278	644
1976	4,193	695	1,320	897	255	606
1977	4,286	702	1,436	946	254	615
Total	21,396	3,524	6,951	4,800	1,360	3,185

Those of you who are familiar with or who have copies of the Board's 1974 Special Study of Fatal, Weather-Involved General Aviation Accidents (which covered a 9-year period) will recognize that the percentages just quoted are not significantly different from those given in 1974.

It is not the intent of this paper to update completely the aforementioned Special Study, but it was considered of interest to provide another look at some of the statistical data available.

For example, what kinds of pilot ratings were held by those involved in the weather accidents delineated in Table 1? The Board lists more than 20 kinds of pilot ratings and also the category of "No Rating." Human nature being what it is, we have found that almost 1.5% of the pilots in weather-involved accidents had no ratings of any kind. On the other hand 55.7% of them had airplane-single-engine-land ratings, 19% had airplane-single/multi-engine-land ratings and about 30% had an instrument rating of some kind. The figures also show that 36% of the pilots with instrument ratings were involved in fatal accidents. One must conclude, therefore, that while an instrument rating is nice to have, it is no guarantee for protection against being involved in a weather accident.

The NTSB categorizes about 65 phases of operation. In an attempt to separate the phases of operations during which most accidents occurred, it was found that the percentages in weather-involved accidents were much the same as the overall general aviation accident picture and that the highest percentage of accidents (35.4%) occurred during the landing phase. This is divided as follows: Level-off/touchdown 15.2%, Roll (fixed-wing) 13.3%, and Final approach 6.9%. Takeoff was next in line with 12.1% and Inflight was next with 11.6%. In all the remaining approximately 60 categories, the percentages were less than 3% in each.

Table 2 was developed to provide some information about the filing of flight plans. There are many more categories than shown, but the table merely highlights the most prevalent citations. Obviously, most pilots do not file flight plans and about three times as many pilots who do not file flight plans are involved in weather accidents as compared with those who do file.

Table 2

U.S. GENERAL AVIATION ACCIDENTS
1973-1977

FLIGHT PLANS

	All Accidents	Weather-Involved Accidents
None	82.7%	73.8%
VRF	10.6%	13.8%
IFR	5.2%	10.5%

The matter of weather briefing is always of interest, particularly those provided prior to an accident which falls in the weather-involved category. Table 3 was developed to show the major sources of weather briefings and as would be expected, briefings by Flight Service Station (FSS) personnel head the list with more than 33% of the briefings having been provided to pilots in all accidents and almost 40% provided to those who had weather type accidents. As you can see, NWS personnel provided less than 3% of the briefings in both cases. It should be noted that in relation to both, all accidents as well as the weather-involved cases, there are large percentages in which there is no record of a briefing having been provided. There is not the implication that the pilots received no briefing (in accordance with the Federal Aviation Regulations for many flights), but that the air safety investigator could not locate such a record, even if there was one. We are well aware that there are many ways to receive a weather briefing and that no record may exist.

Table 3

U.S. GENERAL AVIATION ACCIDENTS
1973-1977

WEATHER BRIEFING

	All Accidents	Weather-Involved Accidents
FSS by phone	21.9%	25.8%
FSS in person	5.2%	5.7%
FSS by radio	6.4%	7.5%
Total	33.5%	39.0%
NWS by phone	1.6%	.7%
NWS in person	1.1%	1.2%
Total	2.7%	2.9%
No record of briefing	41.2%	35.4%
Unknown/not reported	14.0%	13.4%

In connection with the weather-involved accidents, more than 51% of the pilots did get a weather briefing of some kind (when we had evidence of a briefing). Overall, 45% of the pilots received a weather briefing.

The accuracy of weather forecasts is always a concern, but unfortunately, in the cases covering the 5-year period being discussed, more often than not, it was not possible to make such an assessment. It can only be said at this time that in about 45% of the cases, the forecasts were considered to have been substantially correct or the weather was slightly better than forecast. It can also be said that in only about 5% of the cases, the weather was worse than forecast. However, one must note that in more than 50% of the cases our data bank shows only that forecast information was "Unknown/Not Reported."

We are frequently asked to provide information concerning the types of weather phenomena most often associated with accidents. It appears that over the years the list is almost invariably the same in fatal accidents (Table 4-a) and in the non-fatal accidents (Table 4-b). As is quite evident in Table 4, low ceiling, fog and rain top the list as they did in our 1974 study of the fatal accidents; and unfavorable wind conditions, updraft/downdraft and low ceiling are among the top three just as they were in our 1976 study of the non-fatal accidents. The Board uses more than 20 categories of which Table 4 is just an abstract. It should be noted that a category which has been added is wind shear, which has been cited more than 30 times as a cause or factor over the 5-year period covered by this paper.

Table 4-a

U.S. GENERAL AVIATION ACCIDENTS
1973-1977

CAUSE/FACTOR TABLE: WEATHER PHENOMENA

Fatal Accidents

	Cause	Factor	Total
Low ceiling	7	795	802
Fog	6	544	550
Rain	-	298	298
Snow	1	151	152
Thunderstorm activity	6	133	139
Icing conditions	8	107	115

Table 4-b

Non-Fatal Accidents

	Cause	Factor	Total
Unfavorable wind conditions	306	1,258	1,564
Up/down draft	86	249	335
Low ceiling	5	308	313
Fog	5	290	295
Conditions conducive to carburetor icing	10	282	292
Rain	-	160	160

It is common knowledge that most general aviation flying is in the flying-for-pleasure category. It would be anticipated, therefore, that most of the accidents would occur during pleasure flying, and that is quite correct. The Board lists more than 50 categories of flying, and Table 5 lists some of the top categories where accidents are involved.

Table 5

U.S. GENERAL AVIATION ACCIDENTS
1973-1977

KIND OF FLYING

	All G/A Accidents	Weather-Involved Accidents
Pleasure	50.6%	58.8%
Business	7.2%	9.5%
Aerial application	5.8%	-
Instructional/dual	5.3%	-
Instructional/solo	4.3%	-
Air taxi-passenger operations	-	4.2%

As you are well aware, the pilot involvement as a cause or factor in weather type accidents is quite high. Table 6 has been developed to highlight the major types of pilot involvement (of the more than 60 listed by the Board) which occurred in weather-involved accidents during the 1973-1977 period. Four of these top five are the same citations outlined in the 1974 study previously mentioned.

Table 6

U.S. GENERAL AVIATION ACCIDENTS
1973-1977

CAUSE/FACTOR TABLE: PILOT INVOLVEMENT

Fatal Accidents

Pilot-in-command	Cause	Factor	Total
Continued flight in adverse weather	641	12	653
Spatial disorientation	458	1	459
Inadequate preflight preparation or planning	145	157	302
Improper inflight decision or planning	243	51	294
Failed to obtain/maintain flying speed	195	-	195

Air Carrier Accidents

Table 7 is a table for air carrier accidents parallel to Table 1 for the general aviation segment of the industry. While the numbers are not nearly so large, except for the fatalities resulting from the Tenerife ground collision in 1977, the percentage of weather-involved accidents is disturbing. It is perfectly obvious that of the fatal accidents 50% were weather-involved and that compared to the total air carrier accidents, almost 50% were weather-involved. Looking at all accidents, 15.9% were fatal accidents, which is about the same as in general aviation. Ignoring the Tenerife accident as an unusual and hopefully a non-recurring event, there were, on the average, 41 persons killed in each air carrier accident.

Table 7

U.S. AIR CARRIER ACCIDENTS
1973-1977

	All Accidents			Weather-Involved Accidents		
	Total	Total Fatal	Fatalities	Total	Total Fatal	Fatalities
1973	43	9	227	22	4	143
1974	47	9	467	25	4	195
1975	45	3	124	21	2	122
1976	28	4	45	12	3	45
1977	26	5	655	13	2	644
Total	189	30	1,518	93	15	1,149

In discussing air carrier accidents, it was decided not to deal with such matters as pilot ratings, flight plans, weather briefings, and weather forecasts. It was also unnecessary to discuss kinds of flying.

Table 8 lists the weather phenomena, both fatal (Table 8-a) and non-fatal (Table 8-b), most frequently cited by the Board in air carrier accidents from 1973-1977:

Table 8-a

U.S. AIR CARRIER ACCIDENTS
1973-1977

CAUSE/FACTOR TABLE: WEATHER PHENOMENA

Fatal Accidents

	Cause	Factor	Total
Thunderstorm activity	3	2	5
Low ceiling	-	4	4
Rain	-	4	4

Table 8-b

Non-Fatal Accidents

	Cause	Factor	Total
Turbulence associated with clouds and/or thunderstorms	32	1	33
Clear air turbulence	21	1	22
Thunderstorm activity	2	6	8

As in the general aviation area, it was considered of interest to review the pilot involvement as a cause or factor. In the air carrier accidents, the citations were well scattered over more than 35 different types. Table 9 deals with the top citations involved in both fatal (Table 9-a) and non-fatal (Table 9-b) accidents.

Table 9-a

U.S. AIR CARRIER ACCIDENTS
1973-1977

CAUSE/FACTOR TABLE: PILOT INVOLVEMENT

Fatal Accidents

	Cause	Factor	Total
Failed to follow approved procedures, directives, etc.	6	1	7
Improper inflight decisions or planning	3	4	7
Improper IFR operation	4	-	4

Table 9-b

Non-Fatal Accidents

	Cause	Factor	Total
Failed to follow approved procedures, directives, etc.	11	1	12
Failed to initiate go-around	6	-	6
Improper inflight decision or planning	4	1	5
Failed to maintain directional control	5	-	5

As this paper was being completed, some additional information became available which was considered to be of interest to this meeting. The information concerns a 10-year look at some of the air carrier data. For example, for the 10-year period 1968 through 1977, weather was the most frequently cited factor in the United States certificated route air carrier accidents--48.3% in all accidents and 45.3% in fatal accidents. Turbulence was cited as the most frequent causal citation when listing types of accidents--32% of the total. Experience has shown that there are fewer CAT citations than citations of turbulence associated with thunderstorms. The ratio of convective type versus CAT is generally somewhat less than two to one.

General

As most of the attendees know, the Safety Board is not a regulatory agency. One of the most important end products is the safety recommendation addressed to other agencies and organizations. Of course the recommendations are designed to reduce the likelihood of transportation accidents. They do not have the force of law, however, they are made public by many means including publication in the Federal Register. Despite the fact that the recommendations are not mandatory, you may be certain that they carry considerable weight with the recipients. We are aware that they are also of considerable interest to the Congress. As stated previously, each recommendation carries with it an indication of the priority it should be given.

Since the Board became operational in 1967, it has issued 82 recommendations related to weather, most of which have gone to the FAA and/or NOAA/NWS. A review of the status of those recommendations indicates that only 10 of them have been closed with the notation of "unacceptable action." As a "batting average," that's not bad, but the batting average, or acceptance rate, is not as important as the improvements made to facilities, services and procedures leading to an increase in aviation

SECTION V

safety. Obviously, the Board cannot take full credit for all of the changes, but certainly the impetus of many of them has come from the Board and can be attested to be representatives from the FAA and NOAA/NWS.

The statistics provided make it obvious that there continues to be a requirement for a decending trend in weather-involved accidents in U.S. aviation. What are the major problems standing in the way of such a downward trend? Based only on the statistics in this overview, it would appear that pilot training, particularly in the general aviation area, is one of them. Why do so many pilots continue flight in adverse weather? It could be, as the Board has said many times before, that it may well be because of the pilots' mistaken idea of their ability to cope with certain weather situations. Is it because of the lack of continued training after a pilot obtains his initial certificate? Is it the overall quality of the training? Why is he cited so often for inadequate preflight preparation or planning? Is that because of the problems associated with obtaining preflight information? Why are there so many cases in which no record of a weather briefing? Why does weather continue to be so dominant a factor in air carrier accidents? Why, despite airborne weather radar, do there continue to be so many accidents involving thunderstorms? Why so many CAT accidents?

These and many other questions will be discussed over the next three-day period in accordance with the overall objectives of the workshop. I trust that there will be agreement on some solutions to the problems raised and that the workshop will be successful in recommending prioritization and implementation of these solutions.

ATLANTA AIR ROUTE TRAFFIC CONTROL CENTER'S INVOLVEMENT IN AVIATION WEATHER

W. Don Wood

Atlanta Air Route Traffic Control Center

The basic function of the Federal Aviation Administration's Aviation Weather System is to provide timely, accurate, and operationally meaningful weather information to the National Airspace System and its users. I will discuss weather phenomena which may be hazardous to the aircraft or disruptive to the orderly flow of air traffic as it pertains to my particular area of concern--providing air traffic services in the en route environment on a day-to-day basis.

Perhaps a brief look into the past will set the stage for discussing existing methods of distributing weather information throughout the Air Traffic Control System.

Since the inception of air traffic control, the mission has been "to promote the safe, orderly and expeditious flow of air traffic." In pre-radar days, (prior to the late 1950's) weather information was furnished to pilots by air traffic controllers, normally, only when the destination airport was below the prescribed weather minima.

Obtaining weather information that could adversely affect the flight while en route was the sole responsibility of the pilot. When available, air traffic facilities passed along pilot reports of hazardous weather.

The advent of radar throughout the Air Traffic Control System somewhat expanded our weather advisories. Precipitation areas could now be observed on the radar displays and controllers could forewarn pilots, as well as issue headings which would keep them away from these observed areas. Controllers still depended upon pilot reports, however, to obtain valuable information such as intensity and height of observed cells. In this regard, airborne equipment was much more useful than our own radar system. A pilot could scan cells that affected only his altitude, while a controller looked at all cells within his area of coverage. Many times, a pilot would be given advisories on cells that were thousands of feet above or below him. Because weather data blanked the radar presentation so that an aircraft in an area of moderate precipitation could not be flight-followed, systems were developed which would break up these radar returns, better known as clutter, into smaller blocks. This enabled controllers to track aircraft through precipitation areas, but drastically reduced the amount of weather information and data previously available. In some cases, due to these sophisticated

systems, the controller was not aware of precipitation areas which were intensive enough to make flight through them hazardous. But, as it was at the inception, the controller's primary function was to seperate aircraft from each other, and he needed to see them on radar to do so. Although weather flight advisory information continued to occupy an increasingly more important role, it was still considered a low priority item in the scheme of things.

We now move forward almost two decades to the middle 1970's, when computerized systems were installed in air traffic en route facilities. Computerized radar information enabled the controller to adjust the intensity of weather data on his scope. This made it possible for him to track targets through weather without eliminating data. If weather was too heavy, he could temporarily eliminate weather data and then put it back on his scope with the push of a button. Despite these sophisticated systems, weather flight advisories remained an additional service and a relatively low priority item. The air traffic controller still depended upon pilot reports to determine the intensity and height of weather cells, and airborne equipment remained superior in detecting weather at altitude. Neither system had the capability of discerning more than two levels of intensity.

On April 4, 1977, less than a month after your first annual workshop here in Tullahoma, a commercial airline's DC-9 flew into an area of severe thunderstorms over northwest Georgia and crashed after losing power in both engines. The National Transportation Safety Board recommended in its aircraft accident report that the FAA expedite the develoment and implementation of an aviation weather system for FAA Air Traffic Control Centers and terminals. The NTSB proposed that this system should be capable of providing real-time display of either precipitation or turbulence, or both, which would include a multiple intensity classification scheme. By this we mean a method of determining several levels of intensities of precipitation or turbulence. The NTSB further recommended that the FAA establish a standard scale of thunderstorm intensity based on the National Weather Service's six level scale and promote its widespread use as a common language to describe thunderstorm precipitation intensity. The Air Traffic Service has implemented the NTSB's recommendation by indoctrinating pilots and air traffic control personnel in the use of this system. As an example, the Atlanta Center was designated the first site for testing the Enterprise Electronic Corporation's weather radar display. The Atlanta Center receives weather radar data from National Weather Service radar sites at Centreville, Alabama; Athens, Georgia, and Tri-Cities, Tennessee. The use of a site at Nashville, Tennessee, is in the planning stage.

The equipment installed in the Atlanta Center consists of a receiver processor and one color TV monitor for each of the three sites. Precipitation intensity can easily be determined from these units by the color coding associated with the intensity levels established by the National Weather Service. This system allows rapid detection of squall lines and storm cells and their movement. Changes in storm

cell intensity levels are readily detected and assist personnel in rapid identification of storm system characteristics and peculiarities. Intensity levels within a storm are clearly defined and can be displayed individually or in any combination. This allows any intensity level or levels of interest to be isolated and observed on request. The imagery is presented in six selectable contrasting colors against a black background with full data retention. Locations of thunderstorms and squall lines are pinpointed by utilization of geographical reference points common to those used on the radar scope of the air traffic controller.

This information on the location of the more intense weather cells is a valuable tool in maintaining controller awareness of severe weather conditions that could adversely affect flight. This now-time weather information also aids our flow controllers in re-routing aircraft to prevent sector saturation caused by weather conditions.

As a result of our success with the color weather radar program, the FAA recently awarded a $7,000,000 contract for the remoting of numerous National Weather Service radars to Air Traffic Control Centers throughout the country.

The next major improvement in our capability to relay weather information to the pilot in flight was the establishment of the Center weather service unit. This unit, staffed by National Weather Service meteorologists, is responsible for collecting, interpreting and disseminating pertinent weather information. These units were placed in most of the control centers within the past year. For the first time, controllers had immediate access to experts in meteorology.

The controllers' response to the Center meteorologists has been very satisfactory. Information provided to controllers is extremely useful because of its quality and timeliness. The controllers are able to relate this information to the air traffic picture easily, because the meteorologists have done a fine job in learning the language of air traffic control and tailoring their briefings accordingly.

The controllers appreciate the value of this weather data for increasing safety and improving flow control. They are also convinced of the pilot's appreciation for this improved quality of weather information, because of the enthusiastic response of the pilots to the program.

A special training course has been established at the FAA Academy to teach weather coordinators the basics of meteorology. Weather coordinators provide the necessary link between the meteorologists and the controllers since they themselves are fully qualified controllers who are knowledgeable of the entire control area and its special requirements.

We have a vast array of additional tools and communication sources sufficient to stagger the controller of yesteryear between the observation of weather cells on air traffic and weather radar displays and the

observation and reporting of the cells by the airborne pilot. It sometimes appears staggering to us when we try to understand terms such as: WFMU, AWANS, GOES, SAMOS, TIPS, NADIN, ETABS, DABS, EFAS, etc. Just one of these--EFAS, En route Flight Advisory Services--is a rapidly growing service better known as "Flight Watch." While this is primarily thought of as a service for pilots flying under visual flight rules, more and more pilots flying under instrument flight rules are providing observed weather phenomena for our use and for relay to the Flight Watch positions located in many FAA Flight Service Stations. The Center weather coordinator and meteorologists continually share their information with Flight Watch personnel. This constant exchange of observed weather data has removed Center meteorologists from the forecasting business and has made "now-casters" of them. With a high degree of accuracy, controllers are provided information as to trends and severeness of weather areas within radar coverage.

So, what's in store for the future? The FAA's Aviation Weather System preliminary program plan takes us to the mid-1980's and includes methods to detect the location and intensity of turbulence--another giant step forward.

Current plans call for modification of the existing Air Route Traffic Control Center radars to generate and report the range, azimuth and up to eight levels of weather intensity. Data associated with any two levels can be selected and forwarded to the controller's radar scope. This broad range of intensity levels will improve the output interpretation in terms of possible hazards to aircraft.

Additionally, the plan calls for progress in the following areas:

1. Remote National Weather Service weather radars to each center weather service unit.

2. Complete analysis and limited field experimentation of automated weather data distribution functions.

3. Complete installation of satellite receivers at center weather service units, Flight Service Stations and the Air Traffic Control Systems Command Center.

4. Provide an automatic weather data processing and display system at the Air Traffic Control Systems Command Center.

5. Upgrade the weather message switching center for more rapid distribution of surface observations, SIGMET's and AIRMET's.

6. Interface the center weather service units and the FAA Systems Command Center directly with the National Weather Service automation of field operations and services.

Our near-term goals, stretching to 1984, are:

1. Develop and begin to implement, in conjunction with NWS and USAF, a new Doppler weather radar to display turbulence.

2. Apply automated voice response techniques for updating weather advisory broadcasts.

3. Begin implementation of automated weather distribution functions.

4. Implement the National Airspace Data Interchange Network (NADIN) for all intra-FAA weather data communications.

5. Improve handling and dissemination of pilot reports through automation.

6. Implement for the ATC System, a zero to thirty-minute thunderstorm forecasting servce.

This leaves our long-term goals--from 1985 and beyond:

1. Complete the implementation of Doppler weather radar systems.

2. Install color radars for improved display of traffic and weather information.

3. Implement direct address beacon system (DABS) for direct flow of weather information between in-flight aircraft and the Aviation Weather System (AWES).

4. Provide large numbers of pilot access devices and automated voice response systems for direct pilot access to the expanded FSS system data base.

Future research with improved satellite data will undoubtedly result in new concepts and a better understanding of the relationship between satellite data and the dynamics of the atmosphere. In the past ten years, the weather forecast accuracy has increased from approximately 50% to 75%. A pilot requires 100% accuracy and that is the objective in the future.

A completely computerized collection and reporting weather system is not beyond reason. FAA is presently working on a system that will transmit instructions to a display in the cockpit, thus eliminating, or at least reducing, verbage between the pilot and the controller. This direct flow of timely and accurate meteorological information between the computer and the cockpit is indeed a challenging goal, but one which, I believe, will be attained.

EFFECT OF WEATHER CONDITIONS ON AIRPORT OPERATIONS

Daniel F. Ginty

Port Columbus International Airport (PCIA)

Ladies and gentlemen, thank you for inviting me to this important workshop on Meteorological and Environmental Impacts to Aviation Systems. I sincerely appreciate the opportunity to speak and discuss with you the effect of weather conditions on airport operations.

We in airport management feel that the aviation system commences and terminates on the ground, from the point at which the airplane first starts to move, completes its mission and comes to a stop on the ramp. Our aim, as is yours, is to find ways to insure that the entire operation will be accomplished safely and with minimum inconvenience to the travelling public.

We fully realize that we cannot hope to control Mother Nature, but we must discover ways to live in peaceful coexistence with her.

We are continuously confronted with new developments in aircraft design. We now have the equipment and techniques to insure the rapid and safe movement of these aircraft around the world, and it has been proven technically feasible to bring an aircraft into a safe landing without human hands. The runway condition during inclement weather is the one remaining limitation to all-weather operating capability.

We in airport management are aware of this and are learning through intensive programs of scientific and technical research, as well as through exchanges in information regarding operational viewpoints, to shape our environment and truly learn to live in peaceful coexistence with good old Mother Nature in her various moods.

There are basically three areas of adverse weather conditions with which we are concerned: rain, snow/slush, and icing. Let me discuss these one at a time.

Rain. The problem of wet runways can be stated simply with one word--hydroplaning. This situation occurs when surface water collects on the runway. Hydrostatic pressure can then build up in the form of water under the aircraft's tires and reduce or even eliminate the tire-pavement contact at speeds in excess of 120 knots. When this happens the pilot loses braking and directional control.

This condition has all but been eliminated by safety grooving. This process is achieved by cutting transverse grooves the full length and width of the runway. The recommended dimensions of the grooves are

1/4" deep, 1/4" wide, with 1 1/2" spacing between groove centers. This grooving increases the surface water runoff and gives the pilots the best possible braking on a wet surface. In addition to this, grooving has helped to impede ice formation on the runway, and slush appears to dissipate faster.

At PCIA we grooved both of our main runways of 10,700 ft and 6,000 ft last year and highly recommend the process as a valuable maintenance and safety improvement.

Snow/Slush. Airports in the Northern Hemisphere, and in other parts of the world where the climate is similar, are subject to problems resulting from snow/slush and wind. At one time it was possible to accept major snowstorms and high winds as a part of the hazards of flying and we in the industry learned to live with the changing elements and adjust to them. Modern transportation systems, however, with ever increasing numbers of travellers, larger and faster planes, intricate passenger services, busy access routes and constant reminders of safety, can no longer rely on skillful navigation alone, but must have assurance of safe, accurate and functional procedures.

Weather factors are ever present, and simply cannot be discounted at any time. Snow and slush control is a major consideration at many airports and is not attained without expensive and elaborate equipment as well as large numbers of personnel.

A good timely detailed weather forecast can give us time to muster our equipment and personnel and to prepare our plan of action for that particular operation.

Every experienced manager knows that the biggest problem we face is the fact that almost every snow removal operation is different than the one before it. As conditions change so do the methods.

A meteorologist friend of mine once told me that forecasting the time of snowfall; the type of snow, wet or dry; the total accumulation; the wind velocity and the wind direction during and after the storm is probably the most inexact art in the mystical science of weather forecasting. However, the state of the art of weather predictions has steadily moved forward and the improved performance of computer forecasting is encouraging.

The above information is extremely important and must be known and thoroughly thought out if we hope to complete the snow removal operation as expeditiously and economically as possible. At PCIA we are fortunate to have a National Weather Service Station located on the airport, and the communication between the forecasters and my personnel is excellent. The only time I really get worried is when they forecast "snow flurries." On many occasions we have had to plow three or four inches of flurries. The airport manager's feeling for snow is well expressed by my son's poem illustrated in Figure 1. However,

I do keep a copy of the current year "Farmers Almanac" in my desk as a backup.

Seriously though, let me explain why the above information is important prior to commencing the actual snow removal operation. While snowstorms may be the primary reason for the problem situation, it is really the wind that poses the greatest threat, as the wind following the snowstorm will often emanate from a direction completely opposite from that of the snowstorm. Close coordination with the duty forecaster dictates how best to carry out the operation at that time.

Various alternatives relative to wind change, type of snow, etc., result in a need for total coordination between those responsible for snow removal, the local weather service, the traffic controllers and the airport users. At PCIA we establish this working rapport through the formation of a snow committee. We meet prior to every snow season, and as required during the season, to monitor ourselves and our activities, promptly making changes when needed.

Icing. The third adverse condition is ice, and of course I refer to ice forming on the pavement as opposed to ice on the aircraft. Here again we stress the close coordination required between those responsible for snow and ice control and the National Weather Service.

At the present time the most economical and effective method of ice control is by chemical means. One of the first chemicals to be used was urea. This material comes in a pellet from and is distributed on the pavement surface by means of a sand spreader attached to the back of a truck. In order to reduce costs, for many years we used to use a 50/50 mixture of urea and warm sand. The air carriers, however, discovered that the large jet turbines were ingesting the sand when they developed high speeds on the runway for takeoff and landing. This resulted in excessive wear on turbine blades and caused impact damage in other exposed areas such as landing gear and air conditioning openings. As a result we now apply straight urea on the runways when it is used. Another restriction in the use of this material is that it is effective only down to about 20°F at best.

The most effective tool we have for deicing or anti-icing today is a material developed by the Union Carbide Co. called UCAR Runway Deicer. This is a glycol-based liquid which is effective to 0°F that is sprayed on the pavements either prior to or after the ice has formed.

The important feature of this material is its anti-icing capability. It stands to reason that if you have to use it as a deicer you have already lost the runway. You then have to apply the material to break the bond between the ice and the runway surface and then sweep or blow the ice away. This process could take as long as one hour or more on our 10,700 ft runway. Runway closings for this period of time could well require aircraft to divert to another airport, and this is very costly.

We find that with close coordination and communications between our snow removal coordinator and the duty forecaster we have been able to use the UCAR material as an anti-icer. It is applied to the pavement prior to the forecasted freezing rain and prevents the bond from forming between the ice and the runway surface. The judgement in timing of this application is very critical. If it is applied too soon it could be carried away in water runoff and totally lose its effectiveness. We would also have let about $1,000 run down the drain. Another important reason to use this material as an anti-icer rather than a deicer is, once again, cost. The cost of deicing this same runway would have been $4,000.

In summary, I might say we in airport management are striving to achieve better and faster snow and ice control at our airports. We do not want runway conditions to be the one remaining limitation to all-weather operating capability. I feel through workshops such as this and with better communication between all of us involved we will attain our goal.

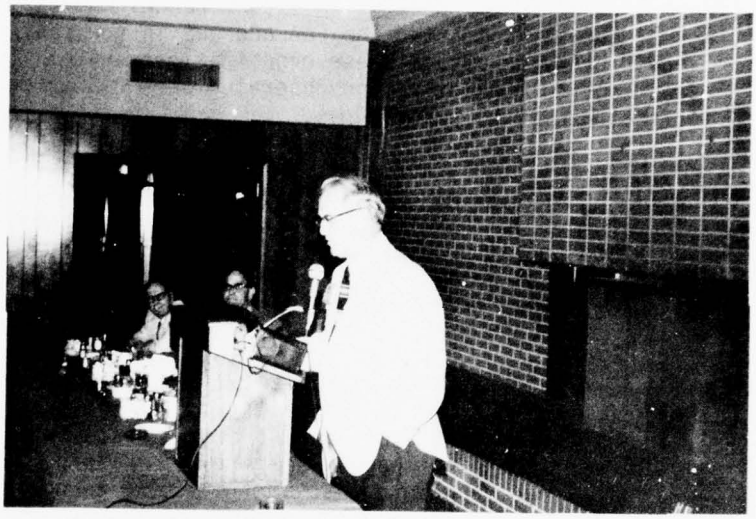
Ladies and gentlemen, I want to express my thanks for letting me participate in your program. It has been my pleasure.



FIGURE 1. SNOW FLURRIES.

SECTION IV

BANQUET PRESENTATION





THE PRIVATE PILOT AND METEOROLOGY (EDITORS' SUMMARY)

Max Karant

Aircraft Owners and Pilots Association

Max Karant began his presentation by emphasizing his surprise at being invited to speak at this conference. He explained how he has continuously lambasted the FAA and NWS in the past and would take this opportunity to attack these organizations again. Inadequacies in forecasting, communicating and observing were emphasized through accounts of actual flight experiences.

In relating a severe icing incident which was encountered during a flight from Washington, DC, to Wichita, Kansas, Max illustrated how the lack of ability to forecast ice was a hazard not only to general aviation but also to transport aircraft. He went on to criticize the observational ability of the control tower by relating an incident of landing through rain and haze although the control tower reported no rain at the airport.

The fact was then expressed that too much dependency is being placed upon instruments in the ATC system and that more human observations are required. Noting that the ATC is a system to supplement the pilot when the pilot cannot see what he is doing because of the weather, Max concluded, however, that airlines tend to operate 100% IFR even when the sun is shining. He emphasized that it is a dangerous fallacy to assume that this system will protect the pilot from others with whom they share the airspace and stressed that the San Diego catastrophe is only the latest of many such results that point out this danger. Max believes that the pilot must be responsible for his flight and must also be held accountable for his errors. The ATC contention that "see and avoid" is obsolete is not acceptable according to Max.

He went on to point out that general aviation constitutes 98% of all civil aircraft in this country. The general aviation fleet is composed of a wide variety of plane types, sizes, shapes and models--each of them designed to do specific jobs of load carrying and communication. The fact that FAA projects the present general aviation fleet of 187,432 to grow to 291,300 by 1989, and our present 784,000 pilots to increase to 1,122,000 pilots while at the same time the airlines probably will not exceed 3,000 units, or less than 2% of the fleet using the airspace, suggests that more attention should be given to the general aviation community.

or acceptance rate, is not as important as the improvements made to facilities, services and procedures leading to an increase in aviation

SECTION V

SHORT PRESENTATIONS







EFFECT OF SPANWISE GUST VARIATIONS

John C. Houbolt

NASA Langley Research Center

The left side of Figure 1 depicts the assumption commonly used in power spectral treatments of gust encounter; that is, the turbulence is considered random in the flight directions but uniform in the spanwise direction The right side of the figure depicts the more realistic situation wherein the turbulence is considered to be random in both the flight and spanwise directions.

The top sketch of Figure 2 indicates that we can consider the random gusts to be composed of the sum of a number of sinusoidal gust components. It has been found that the long wavelengths and the very short wavelengths do not contribute significantly to airplane loads or response. The intermediate wavelengths, on the order of from one to ten times the span of the airplane, are found to be the major contributors. The middle two sketches show the result of the uniform spanwise gusts assumption on the vertical force and rolling moment. The left sketch shows that the entire span is effective in producing a vertical force. The right sketch shows that the right and left wings produce equal upward forces, and thus no rolling moment is produced. Thus a failing of the uniform spanwise gust assumption is that no rolling moment can be produced. For the lower two sketches we show the influence of a sinusoidal gust component which has a wavelength roughly equal to the airplane span. On the left we see that the upward force is essentially cancelled out by equal downward forces. Thus for this component, and for the smaller wavelength components, there is very little vertical force production. On the right we see in contrast that this wavelength component is a major producer of rolling moment. We thus need to take into account all the spanwise components to accurately establish the rolling moment produced by gusts.

Figure 3 gives three of the key reasons why spatial or spanwise variation of gust is important. Item 1 deals with the N_0 parameter, which refers to the number of times per second the response quantity of interest crosses the 1-g load level with a positive slope. This N_0 value is found as the radius of gyration of the area under the output spectra about the vertical axis. If the gusts are treated as uniform in the spanwise direction, N_0 evaluates to infinity by our normal analytical approach procedures. If we alter the non-steady aerodynamics we can make the tail of the output spectra converge faster; a finite but unrealistically high value of N_0 results. If we take into account the spanwise variation, the tail of the spectra converges much faster due to the cancelling effects discussed in Figure 2; the N_0 value is now found to be correctly evaluated. Item 2 indicates that the proper treatment

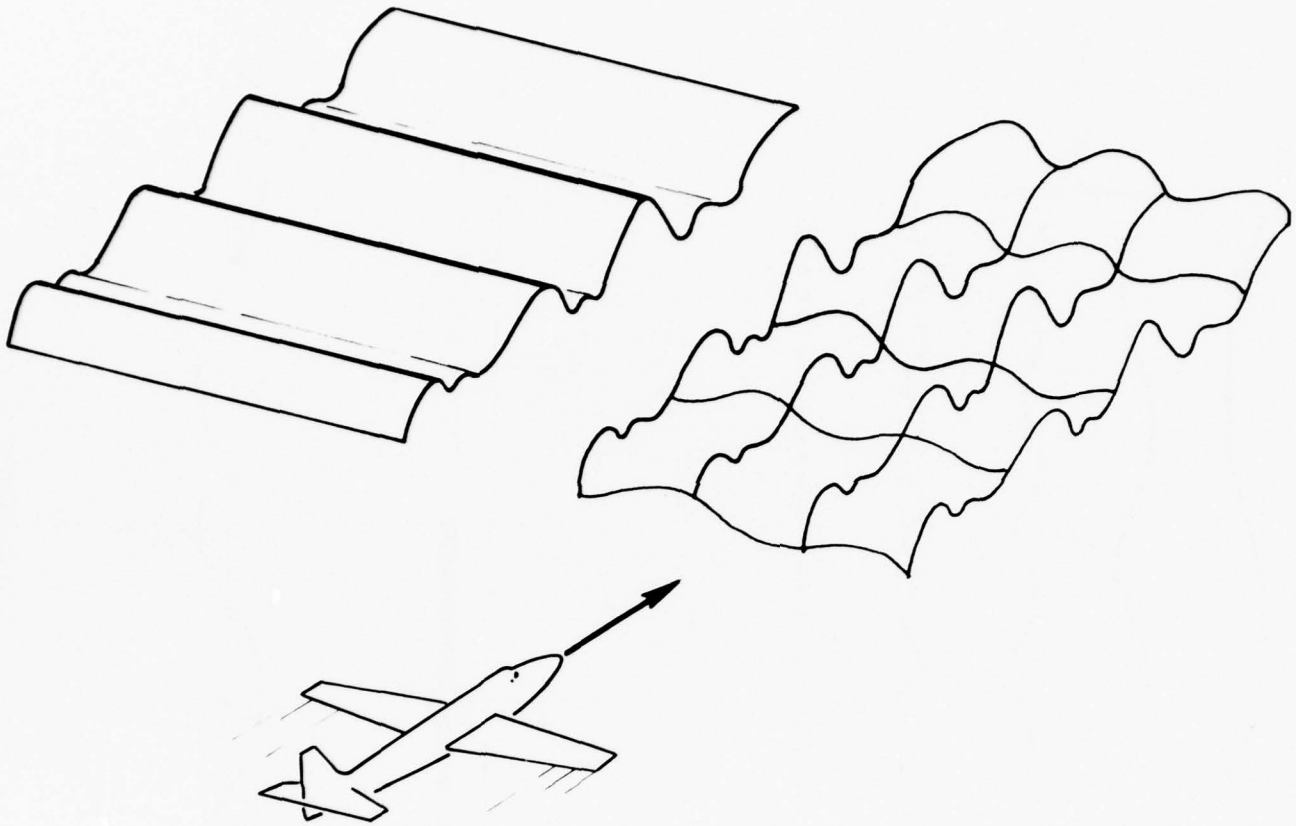
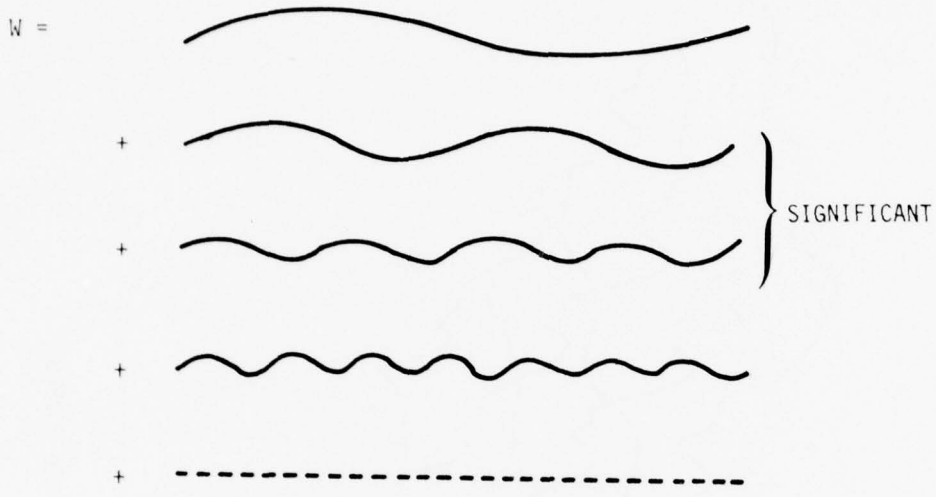


FIGURE 1. ASSUMPTION OF TURBULENCE MODELS.



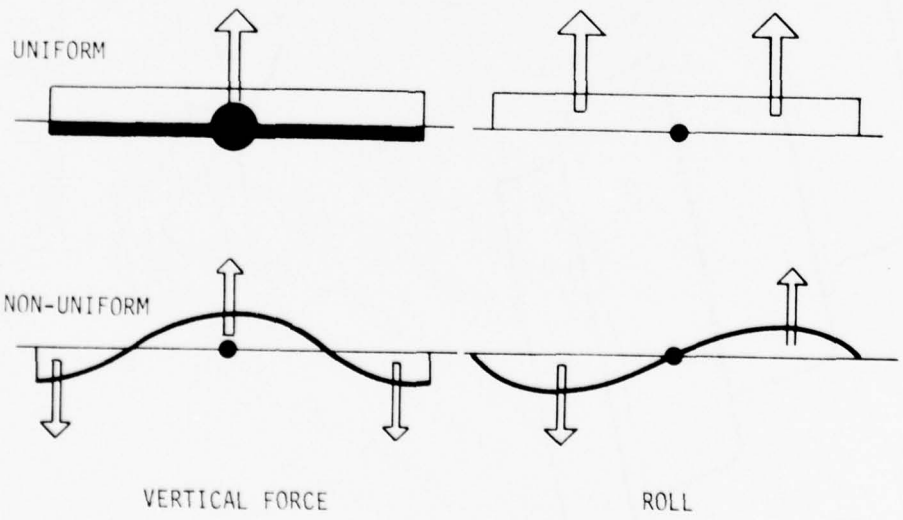
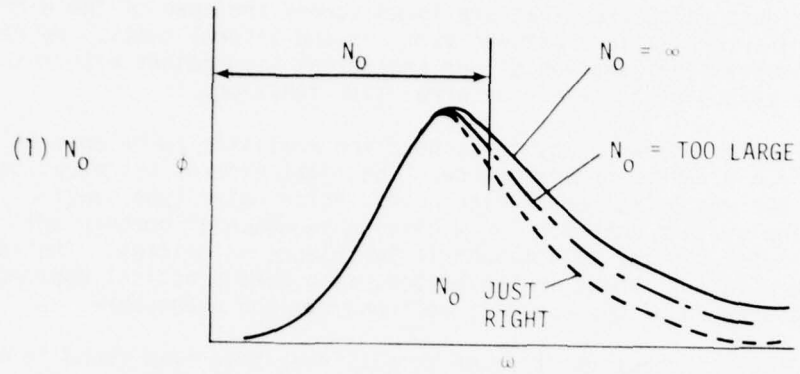


FIGURE 2. RANDOM GUSTS ASSUMED TO BE COMPOSED OF SINUSOIDAL GUSTS.



(2) ROLLING MOMENTS

(3) CROSS-CORRELATION

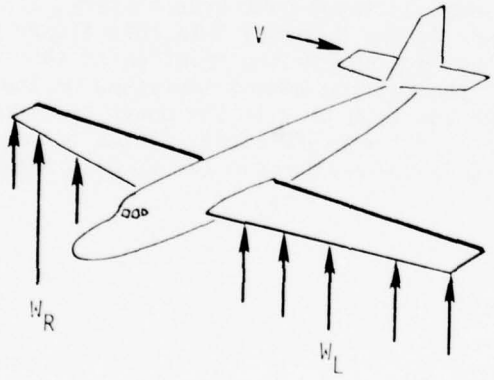


FIGURE 3. THREE OF THE KEY FEATURES OF SPATIAL OR SPANWISE GUST VARIATIONS.

of non-uniform spanwise gusts does lead to a rolling moment. Item 3 indicates that we are interested in general about the cross-correlations of the gust velocities that are found across the span of the wing and in the cross-correlations between vertical and lateral gusts. We need experimental confirmation of our analytical assumptions with respect to the makeup of these cross-correlation functions.

Figure 4 shows a way for generating realistic turbulence velocities from a random number source. The right side of the equation represents the random numbers (which have a white noise type spectra). Solution of this equation for w gives a sequence of numbers which have a character similar to atmospheric turbulence velocities. The spectra of the w values, shown in the bottom, is a good practical approximation to the spectra of gust velocities found for the atmosphere.

Figure 5 shows the type of results that have been found in an analytical study to evaluate the rolling moment spectra that develops on an aircraft due to the spanwise gust variations. The characteristic shape of the spectra is as shown. The peak is found to be associated with turbulence wavelengths slightly larger than the wing span, as depicted in Figure 2. The parameter X is seen to be a function of the frequency ω, the forward speed V, the scale-to-chord ratio L/c, and the wing aspect ratio A.

Figure 6 shows the equation that was also derived in the study which allows for the generation of a timewise history of the random rolling moment that is felt by the airplane due to gusts. The quantity y in this figure represents an input gust time history, as found by the technique shown in Figure 4; the quantity X in this figure represents the rolling moment. Thus, a step-by-step solution of this equation gives a time history of the rolling moment impressed on the airplane due to gusts. The power spectrum of X is the power spectrum shown in Figure 5. The dependence of the coefficients of the equations on velocity V, chord c, and scale-to-chord ratio L/c is also shown.

$$\dot{W}_n + aW_n = r_n$$

$$a = \frac{V}{L}$$

r_n - from random number generator

W_n - gust velocity

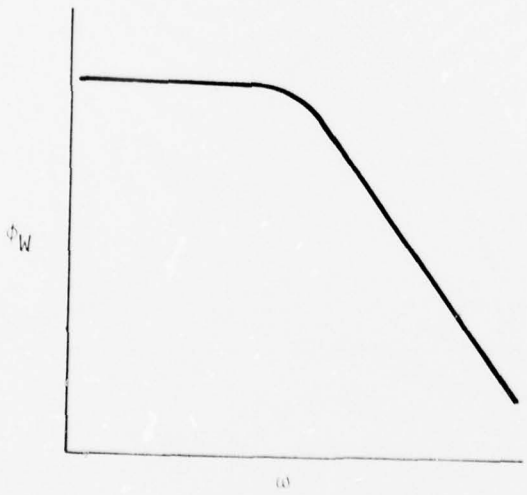
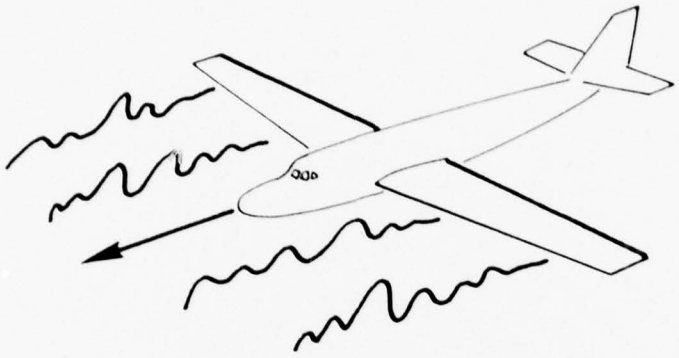
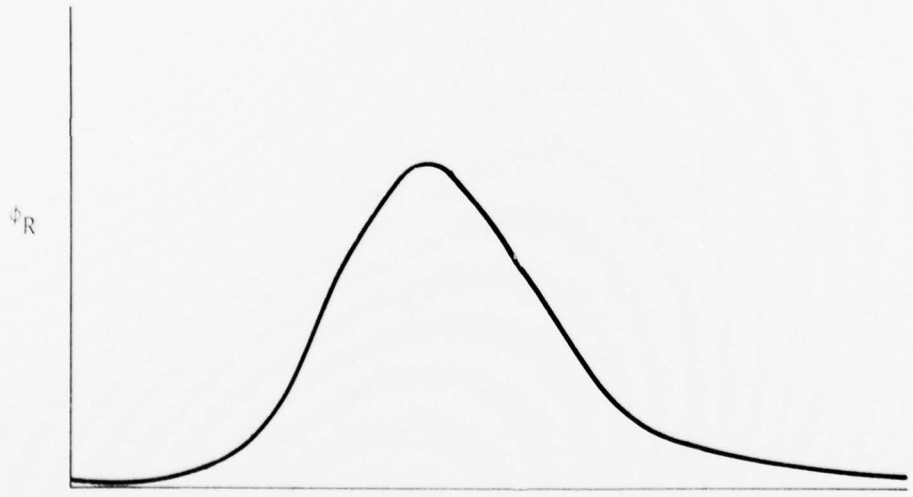


FIGURE 4. GUST SIMULATION.





$$X = \frac{C}{2L} A\sqrt{1 + \left(\frac{\omega C}{2V}\right)^2 \left(\frac{2L}{C}\right)^2}$$

FIGURE 5. ROLLING SPECTRA.



FIGURE 6. ROLL MOMENT GENERATION.

THE T-28 THUNDER/HAILSTORM PENETRATION AIRCRAFT

John Prodan

Institute of Atmospheric Sciences

The purpose of my presentation this morning is to tell you about a unique aircraft--one almost literally designed to "go where angels fear to tread." The aircraft is a highly modified, former Air Force trainer--the T-28--originally built by North American Aviation (now Rockwell International) in 1949.

In the latter part of the 1960's, the idea of modifying an aircraft to take scientific measurements within active hailstorms emerged. As a result of studies conducted by Dr. Paul B. MacCready of Meteorology Research, Inc., under subcontract from the Institute of Atmospheric Sciences (IAS) of the South Dakota School of Mines and Technology (SDSM&T) and supported by the National Science Foundation (NSF), the decision was made to proceed with such a modification. The aircraft selected was the North American T-28 trainer used by the Air Force and Navy for pilot training (Figure 1). An aircraft was located and purchased on the commercial market. Analysis showed that armoring the wing, tail, canopy and cowling would permit the airplane to safely penetrate all but the severest of hailstorms. Accordingly, the following modifications[1] were made:

- The leading edges of the wings were armor plated with 0.090 inch heat-treated aluminum.
- The upper surfaces of the wings and tail were armor plated with 0.032 inch heat-treated aluminum.
- The leading edges of the engine cowling were armor plated with 0.125 inch aluminum.
- The canopy was replaced with a much stronger unit constructed of 0.125 and 0.090 inch aluminum and having side panels of 0.60 inch stretched acrylic. The windshield was replaced with panels of 0.75 inch stretched acrylic (Figure 2).
- Heavy aluminum grills were installed over the air intakes of the carburetor and oil cooler to restrict hail from entering.
- The propeller governor and the push rod housings were armored to prevent hail damage.

[1]Most modifications were accomplished in the 1968-1971 time period and the rest as the need arose.



FIGURE 1. VIEW OF ARMORED T-28 AIRCRAFT IN FLIGHT. (PHOTO BY ROGER ROZELLE--AOPA PILOT MAGAZINE)



FIGURE 2. REDESIGNED T-28 CANOPY FOR HAIL PROTECTION.

Along with armor plating the aircraft structure and strengthening the canopy, other modifications were made to enhance the performance and survivability of the airplane. These included:

- Propeller and carburetor alcohol anti-ice systems were installed.
- A Wright R-1820-86A engine delivering 1425 hp to a Hamilton Standard three-bladed propeller was installed.
- The fuselage structure was strengthened to support the larger engine (1425 hp vs. 800 hp from the original engine).
- An improved fuel system was installed.
- A new nose landing gear was installed along with the nose gear torque box.
- A larger oil cooler system was installed.
- A new oxygen system was installed.
- As a result of Air Force experience, wing spar caps were added to strengthen the wings for increased turbulence during storm penetrations.
- The horizontal stabilizer was replaced with one designed to withstand buckling under turbulent flight loads.
- The 100 volt-ampere inverters were replaced with 250 volt-ampere inverters.
- The rear cockpit controls and flight instruments were removed and replaced by the primary instrumentation recording system.
- PMS data processing equipment was mounted on an instrumentation platform in the baggage compartment area.
- The T-28 avionics were replaced with modern reliable equipment.

The net result of these modifications is that the T-28 can safely fly through thunderstorms and hailstorms with hail of up to 7.6 cm (3 in) in diameter. At the same time, the instrumentation and data gathering systems carried by the T-28 will take measurements of the internal characteristics of the storm that are of interest to research scientists.

At the present time, the T-28 has two instrumentation systems that allow measurement of the variables listed in Table 1. The primary recording system consists of a Precision Instruments Model 1387 computer-compatible magnetic tape recorder and a Monitor Labs Model 9100 multiplexer unit. This system is capable of recording 30 BCD digits of

Table 1

VARIABLES RECORDED BY T-28 INSTRUMENTATION SYSTEM

Variable	Instrument	Range of Measurement
State:		
Static Pressure (Altitude)	*Rosemount	0 to 15 PSI
	*Ball Engineering	0 to 27,000 ft (8.2 km) MSL
Total Temperature	Rosemount	-25 to +25°C
	*NCAR Reverse Flow	-25 to +25°C
Aircraft Navigation & Performance:		
Attitude	Servomechanisms angle-of-attack vane	-15 to +15°
	*Pitch (Humphrey vertically-stabilized accelerometer)	-50 to +50°
	*Roll (Humphrey vertically-stabilized accelerometer)	-50 to +50°
Navigation	Heading indicator	0 to 360° magnetic
	*CESSNA DME	0 to 200 n mi
	*NARCO DME	0 to 100 n mi
	NARCO COM/NAV (2 units)	0 to 360° from station
	*NARCO NAV	0 to 360° from station
Performance	Ball Engineering variometer (rate-of-climb)	-6000 to +6000 ft/min (-30 to +30 m/s)
	*Rosemount dynamic pressure (Ind. airspeed)	- 3 to +3 PSI
	*NCAR True Airspeed Computer	0 to 250 knots (128 m/s)
	*Humphrey vertically-stabilized accelerometer	-1 to +3 g's
	Giannini manifold pressure	0 to 50 in Hg
Hydrometeors:		
Cloud droplets	Johnson-Williams LWC	<50 μm dia (liquid only); 0 to 6 g/m^3
	*Particle Measuring Systems FSSP	3 to 45 μm dia; adjustable
Rain, graupel, snow	Williamson Foil Impactor	1 to 20 mm dia
	*Particle Measuring Systems OAP-2D	31 to 1000 μm
	*Cannon Particle Camera (alternates with hail spectrometer)	Approx. 50 μm up
Hail	Laser Hail Spectrometer (alternates with Cannon camera)	4.5 to 50+ mm dia

*Furnished by NCAR.

information plus 32 channels of analog data converted to digital form. The basic recording interval is once each second, although some of the variables are sampled twice during each one-second cycle to provide higher frequency response. In addition, a Pertec digital recorder, which is used to record particle size information from the PMS probes, serves as a backup recorder. It records all of the digital and some of the analog data that are recorded on the primary system.

A two-channel audio recorder records all communications transmitted and received by the T-28 along with the pilot's comments through a "hot mike" capability on one channel, and records precipitation and hail impact noises on the other channel. These comments and recorded impact noises are invaluable in subsequent data anlysis. A side-looking remote controlled 8 mm movie camera is used for qualitative pictures of the storm environment.

Data sensors are mounted on the underside of the wings (Figures 1 and 4). The basic wing structure is that of a T-28A and, as such, has one "hard point" external stores mounting location for each wing. The Johnson-Williams LWC sensor (Figure 3) is located on the right wing near the wing tip. Two total pressure sources are mounted on the right wing (Figure 4)--one for the pilot's airspeed indicator and the other for the data system. The angle-of-attack measuring vane is also mounted on the right wing. The PMS Forward Scattering Spectrometer Probe (FSSP), the PMS Optical Array Spectrometer Probe (OAP-2D), and the Williamson Foil Impactor are mounted on the right wing pylon (Figure 5). On the left wing pylon mount, the one unit of the Cannon Particle Camera (Figure 6) alternates with one for the Laser Hail Spectrometer. The remaining unit for each system is mounted just outboard of the pylon location. At the wing tip, two temperature probes are mounted (Figure 7) with the National Center for Atmospheric Research (NCAR) Reverse Flow instrument just inboard of the Rosemount instrument.

Data processing for the T-28 system is conducted in two phases. The first phase is the "quick look" reduction and provides "rapid recall" plots of the data. In this phase, the data tapes from the Monitor Labs 9100 and Pertec recorder units are sent to Rapid City, South Dakota, and Boulder, Colorado, by the most expeditious means available for immediate processing by the IAS and NCAR respectively. For example, in SESAME '79 air freight is used. Computer-generated plots (Figure 8) of the reduced data from the 9100 recorder are transmitted via telecopier to the field site--usually within a few hours after receiving the data tapes in Rapid City. The reduced PMS data from the Pertec recorder are reviewed at NCAR immediately and then sent to the field in microfilm form for comparison with the other data. This technique has been a key element in early detection of equipment malfunctions and minimizing lost research opportunities. A further advantage is availability of the data in the field for on-the-spot preliminary analysis while the conditions of observations are still fresh in everyone's minds.

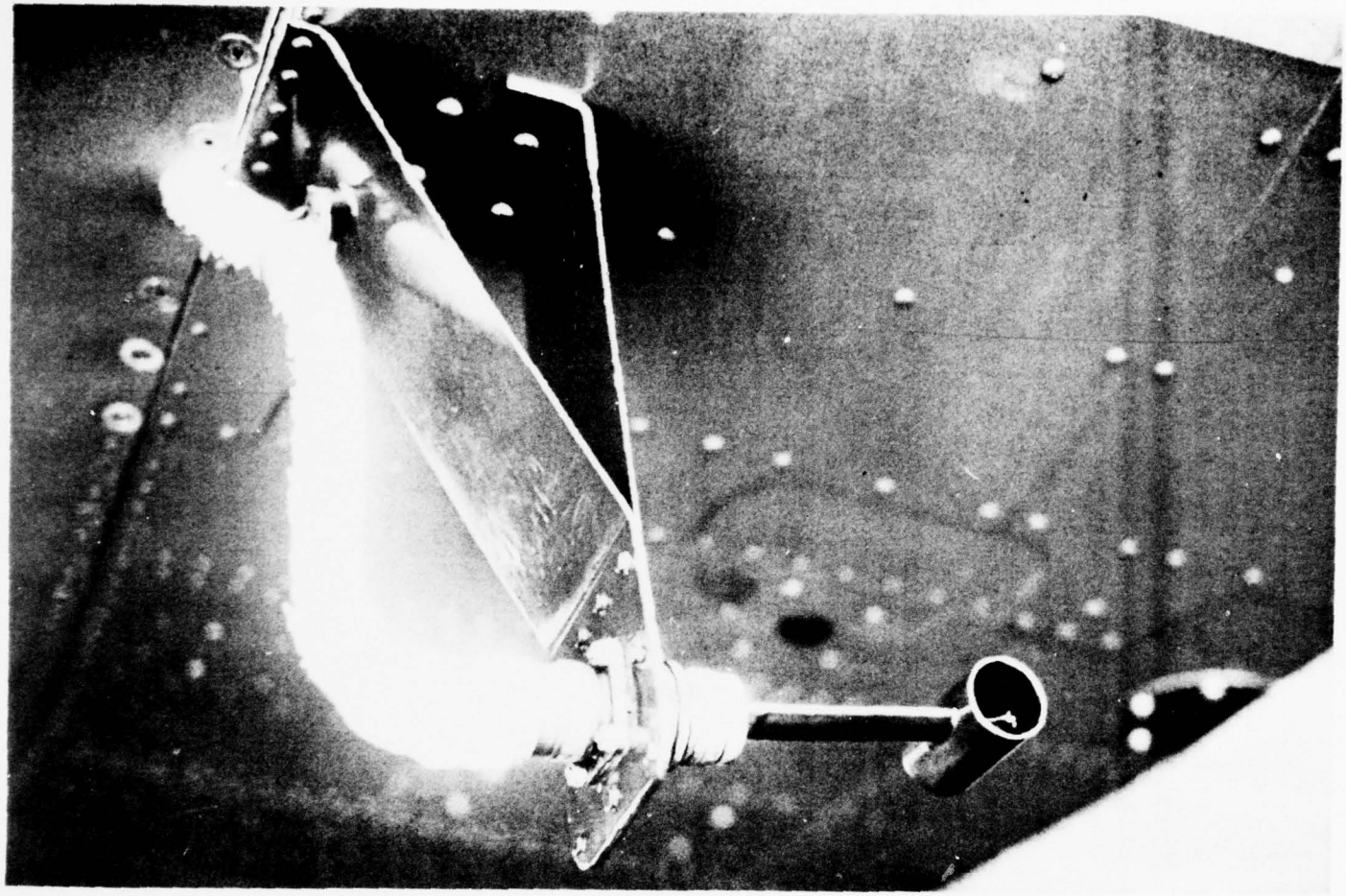


FIGURE 3. JOHNSON-WILLIAMS LIQUID WATER CONCENTRATION MEASURING INSTRUMENT.

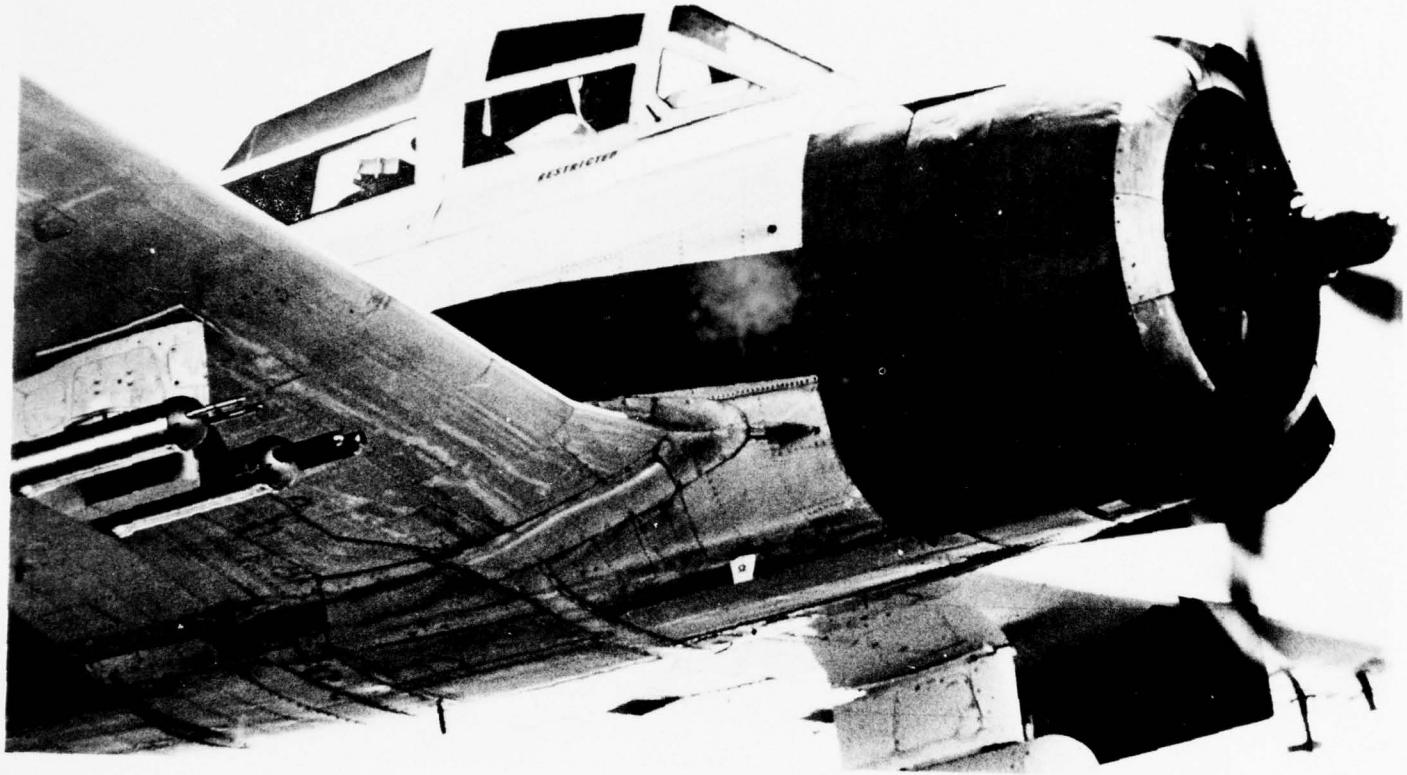


FIGURE 4. T-28 SENSORS WITH THE TOTAL PRESSURE HEADS ON THE LEFT OF THE ANGLE-OF-ATTACK VANE (SMALL POST). (PHOTO BY ROGER ROZELLE--AOPA PILOT MAGAZINE)

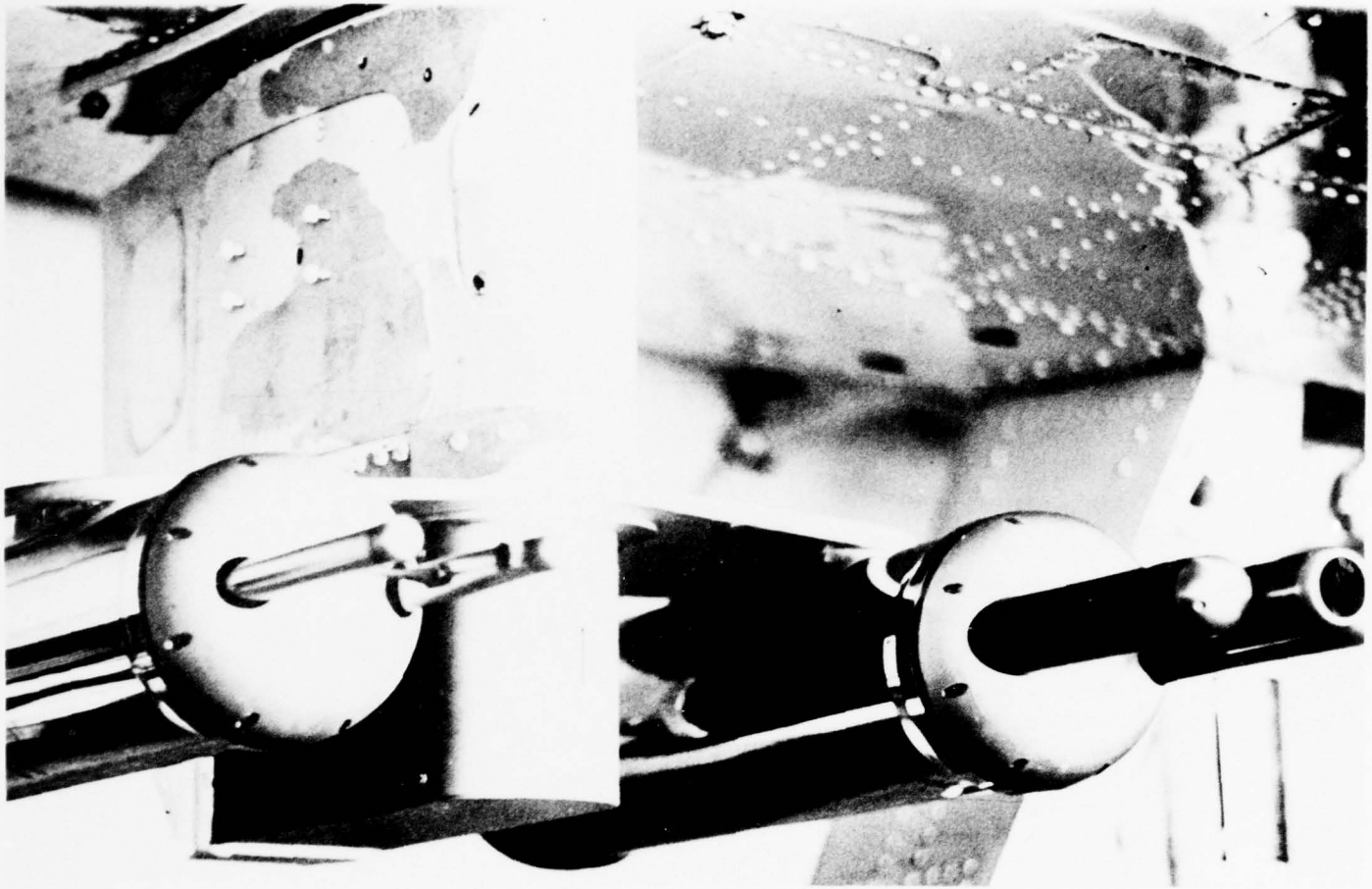


FIGURE 5. T-28 RIGHT WING PYLON WITH THE PMS PROBES (OAP-2D LEFT AND FSSP RIGHT) AND THE FOIL IMPACTOR (CENTER).

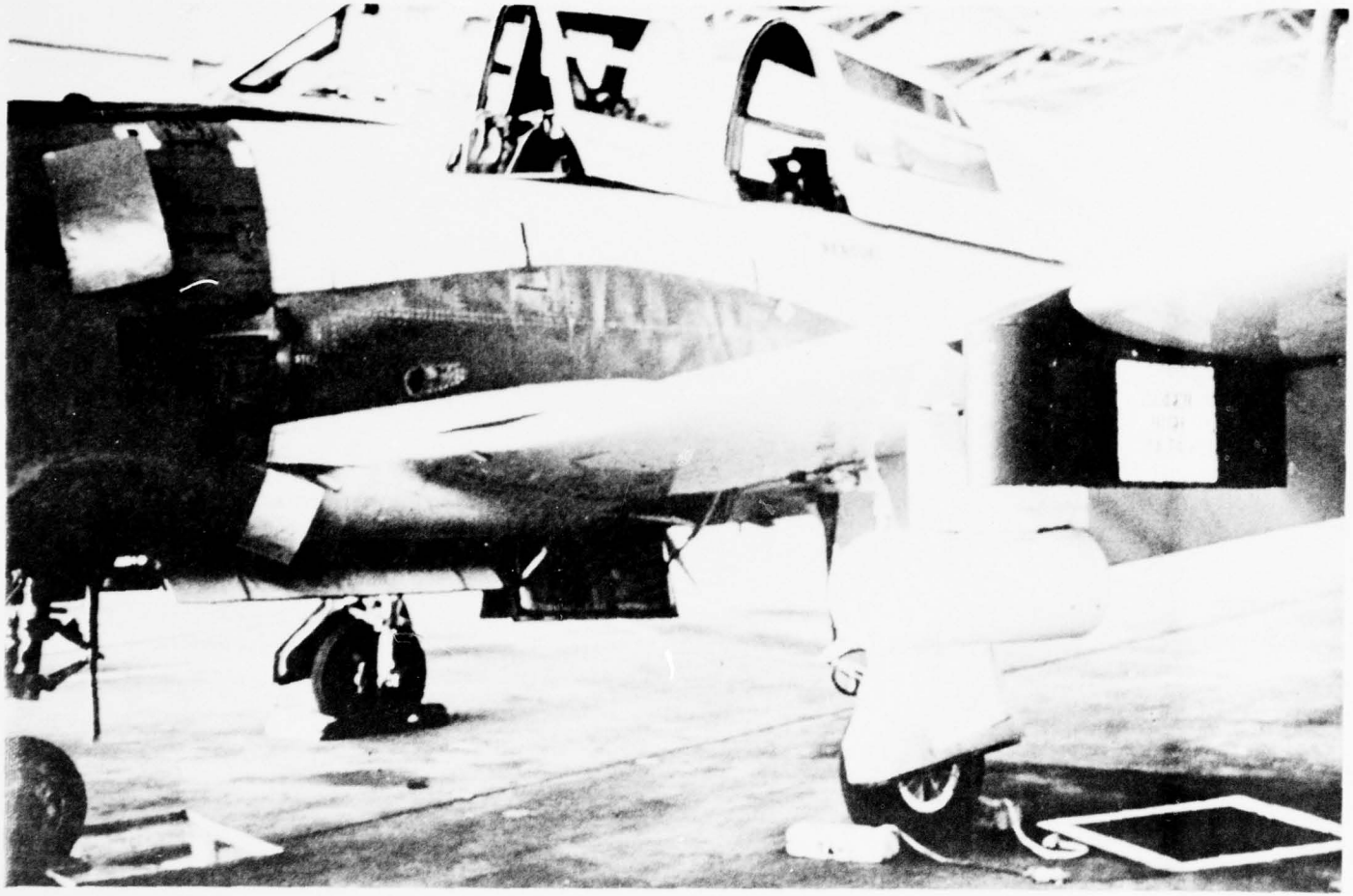


FIGURE 6. T-28 LEFT WING PYLON WITH THE CANNON PARTICLE CAMERA (WHITE POD) AND STROBE LIGHTING POD (BLACK).

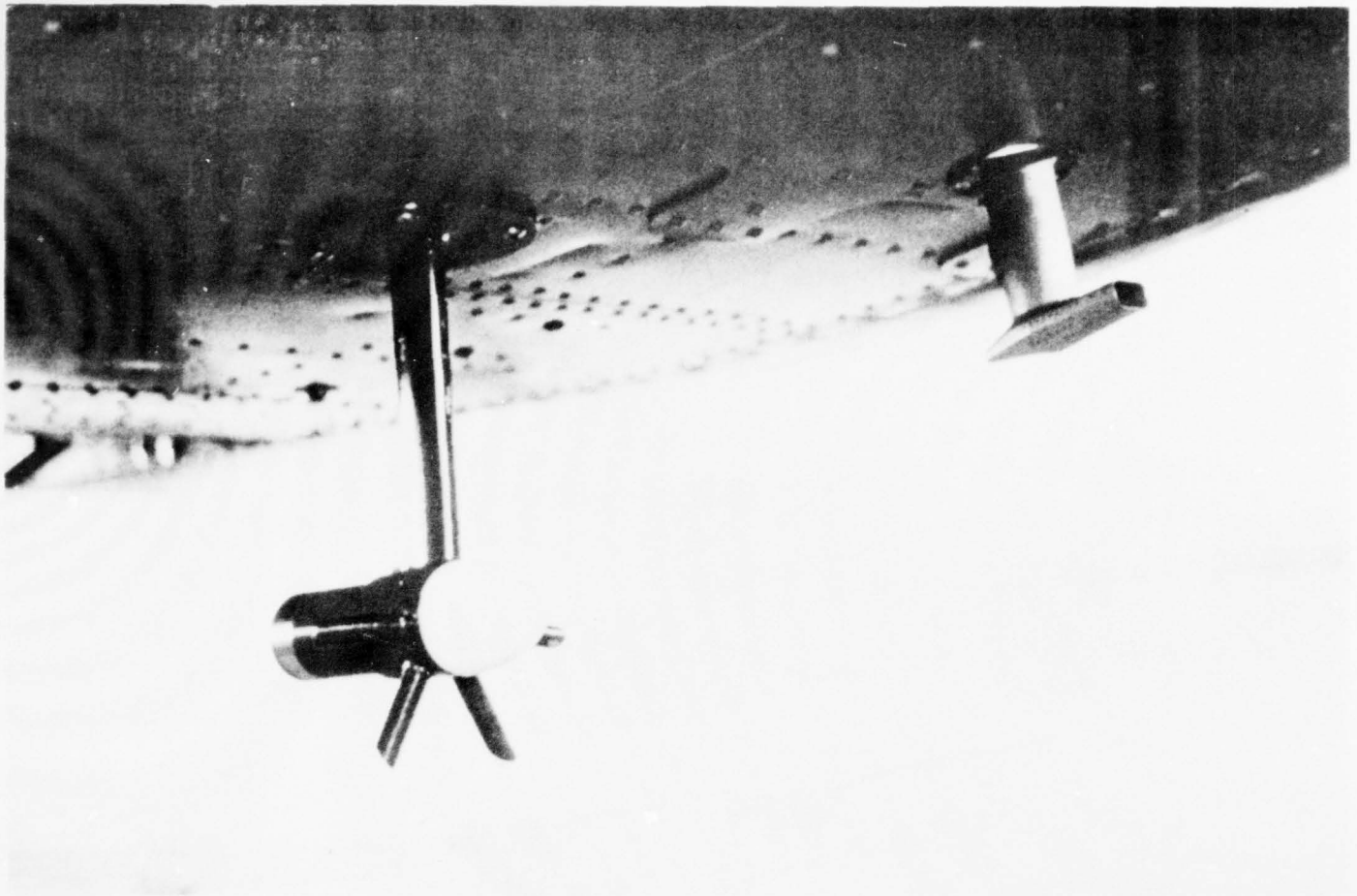
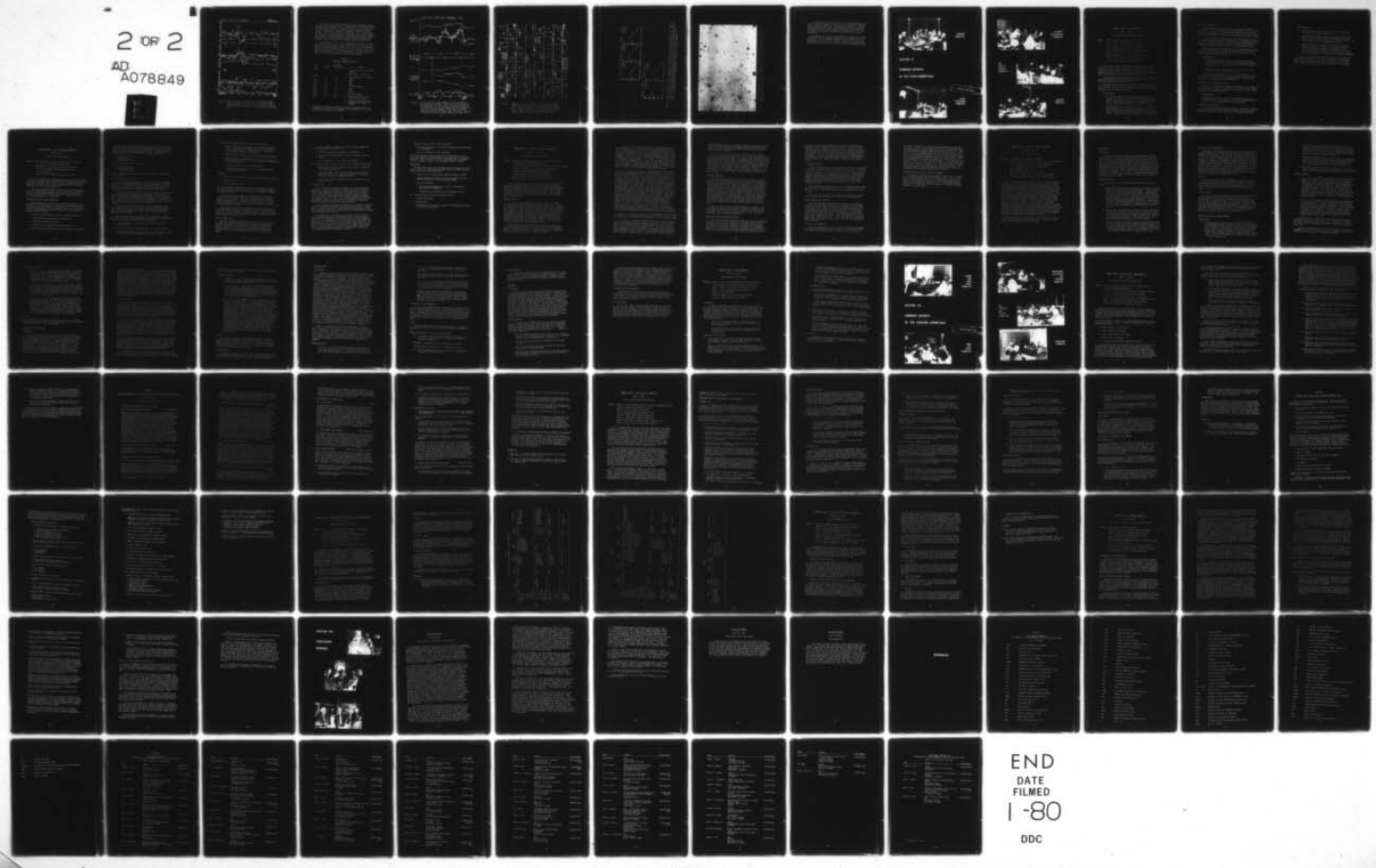


FIGURE 7. T-28 TEMPERATURE SENSORS--NCAR REVERSE FLOW (LEFT) AND ROSEMOUNT (RIGHT).

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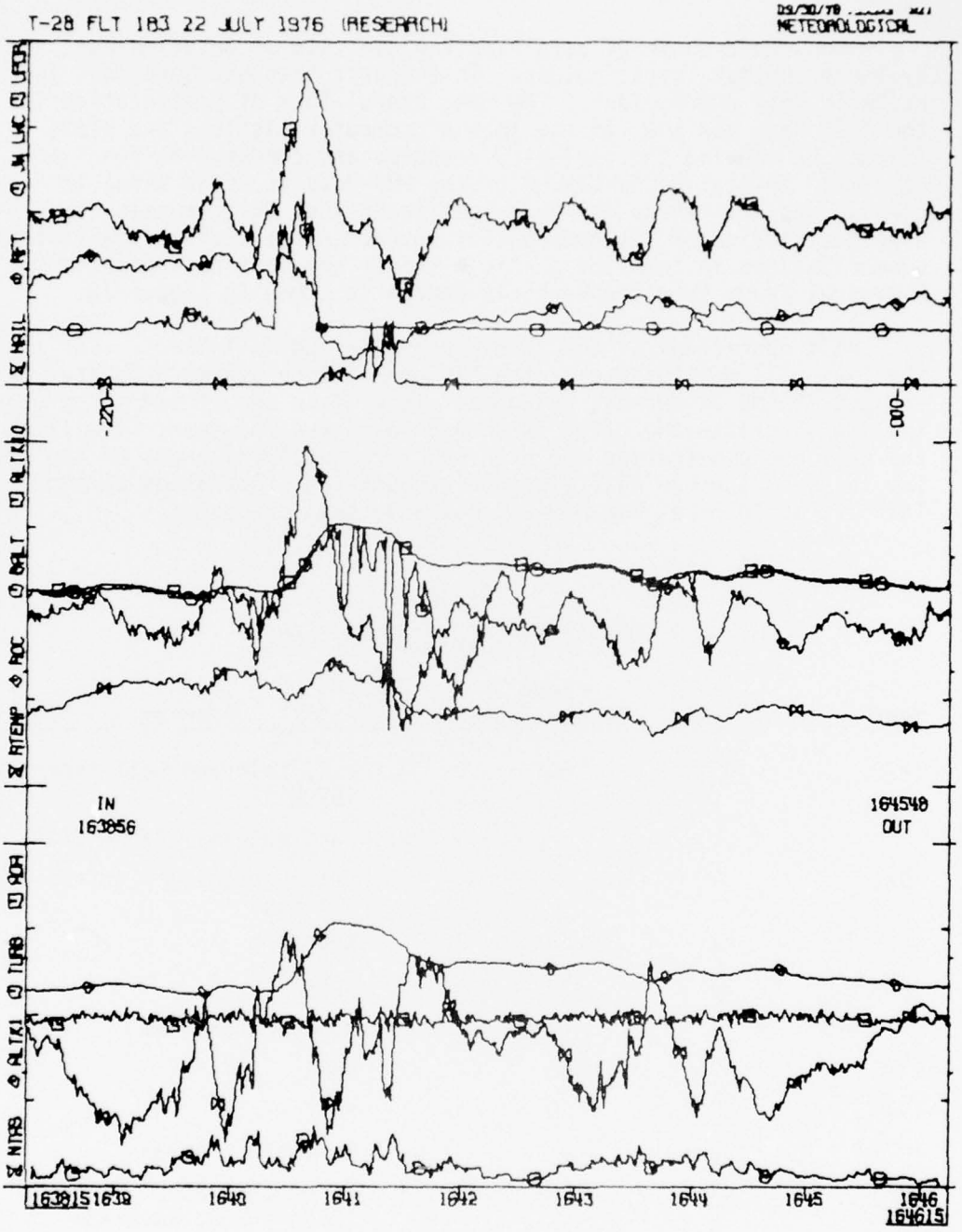


FIGURE 8. EXAMPLE OF REDUCED METEOROLOGICAL DATA FROM RAPID RECALL OUTPUT OF FLIGHT 183, 22 JULY 1976. THE TOPMOST TRACE INDICATES UPDRAFT SPEED (SCALE +25 TO -25 M/SEC), AND THE OTHER TRACES DEPICT VARIABLES INDICATED ALONG THE LEFT-HAND EDGE.

The second phase of data handling consists of detailed analyses by the principal investigators. In the past this has been done jointly at Rapid City and Boulder. The most useful form of presentation for the T-28 data has been in the form of computer listings and plots (Figure 9) showing the variables measured and computed as functions of time. Initial presentation of the PMS data is as is shown in Figures 10 and 11. There are numerical techniques which permit comprehensive description of the hydrometeor characteristics and allow various summarizations in terms of particle number and mass concentrations. A typical frame from the Particle Camera is shown in Figure 12.

Past operations of the T-28 are summarized in Table 2. For 1979, the T-28 will participate in the National Severe Storms Laboratory's Project SESAME at Norman, Oklahoma. It will be one of two storm penetrating aircraft--the other is an Air Force F-4--however, it will be the only one penetrating the high radar reflectivity areas of the storm (up to 55 dBz) where hail might be encountered. Operation during TRIP '79 at Socorro, New Mexico, has also been proposed.

Table 2

OPERATIONAL SUMMARY BY YEARS

Year	Flights	Cloud Penetrations	Program
1970	40	20	1. N.E. Colorado Hail Experiment (NECHE)
			2. Hail Models - Rapid City
1971	21	--	Engine problem - no research flights
1972	54	83	NHRE
1973	38	27	NHRE
1974	8	--	No field program
1975	40	48	NHRE
1976	50	60	NHRE
1977	18	--	No field program
1978	47	108	1. Convective Storm Division (CSD) - N.E. Colorado
			2. Thunderstorm Research International Program (TRIP) - Florida

The flights listed include research flights, maintenance flights, and equipment test flights, so the number of cloud penetrations is a better guide to the amount of data collected.

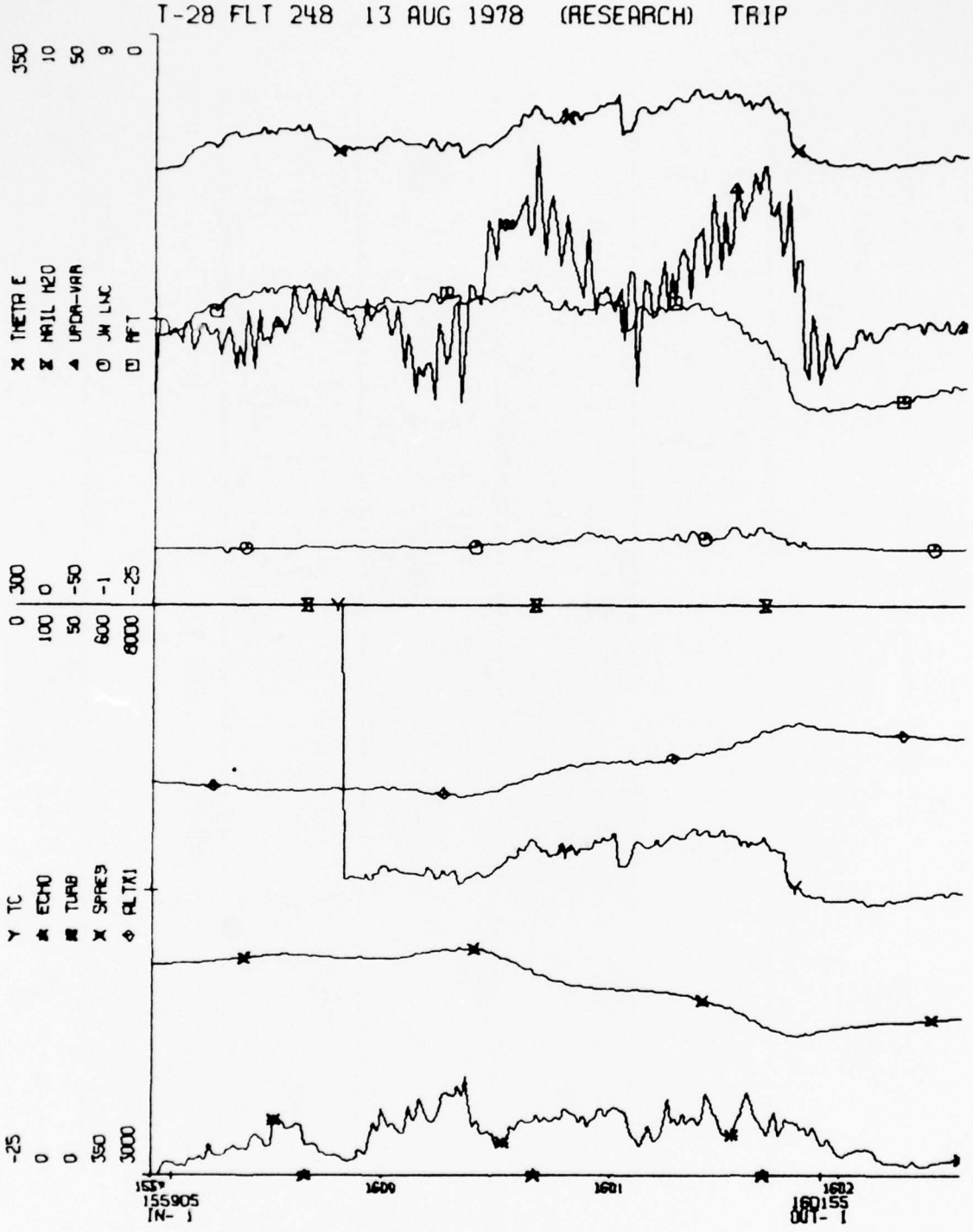


FIGURE 9. PLOT OF DATA FOR A 4-MIN SEGMENT OF THE T-28 FLIGHT ON 13 AUGUST 1978 IN FLORIDA. POINTS OF CLOUD ENTRY AND EXIT ARE INDICATED BY THE IN-1 AND OUT-1 MARKS ON THE ABSCISSA; THE TIME SCALE (EDT) CAN BE CONVERTED TO AN APPROXIMATE DISTANCE SCALE USING THE NOMINAL FLIGHT SPEED OF 6 KM/MIN. VARIABLES PLOTTED ARE INDICATED ALONG THE ORDINATE, WITH THE SCALE RANGE AND PLOTTING SYMBOL INDICATED FOR EACH CURVE.

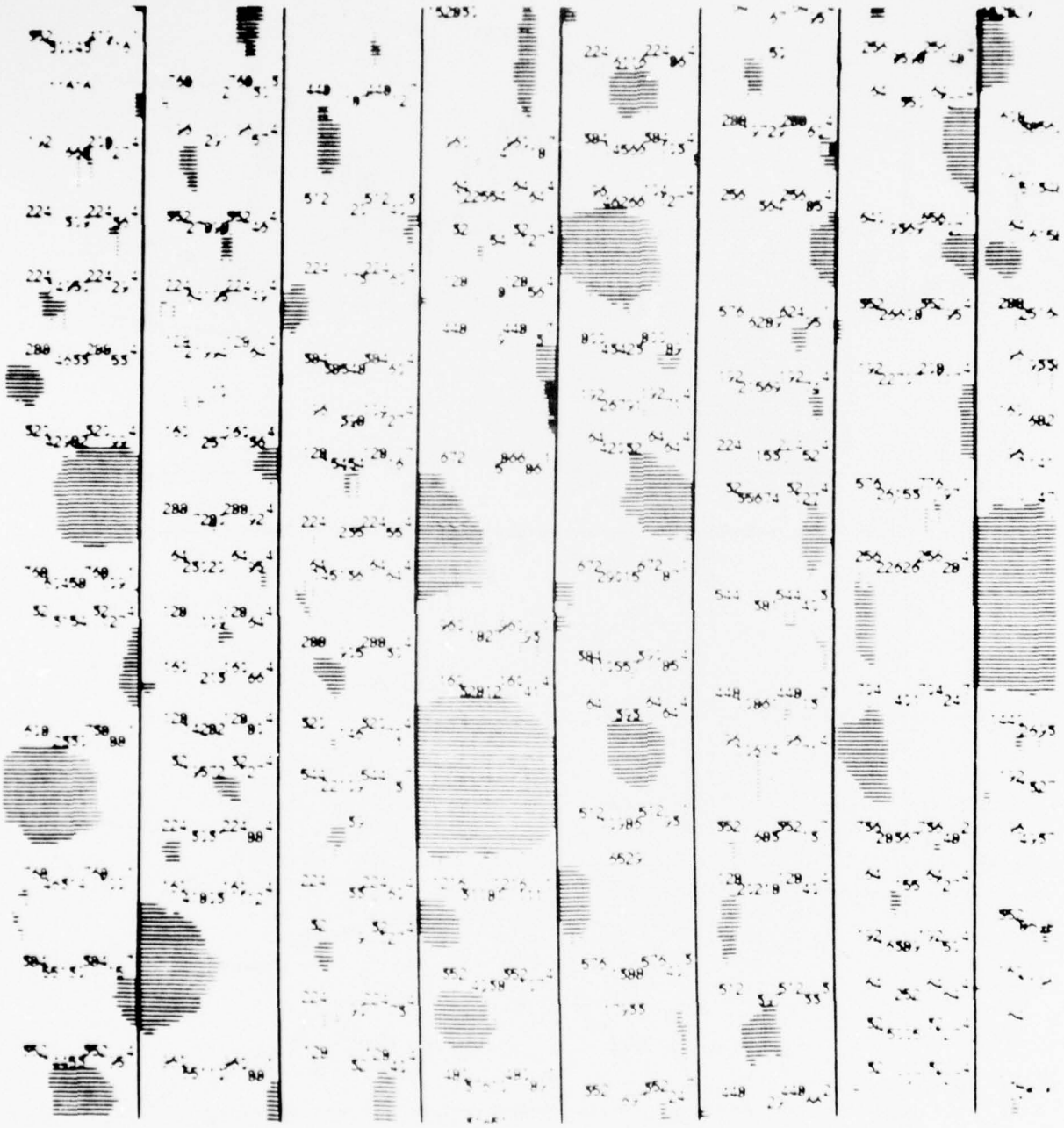


FIGURE 10. SAMPLE OF THE PARTICLE IMAGES OBTAINED BY THE PMS OAP-2D PROBE DURING A T-28 PENETRATION IN FLORIDA ON 13 AUGUST 1978. DISTANCE BETWEEN THE HEAVY BARS REPRESENTS APPROXIMATELY 1 MM, GIVING AN IDEA OF THE PARTICLE SIZES REPRESENTED. NUMBERS REPRESENT INFORMATION ABOUT PARTICLE CHARACTERISTICS, DISTANCE BETWEEN PARTICLES, ETC.

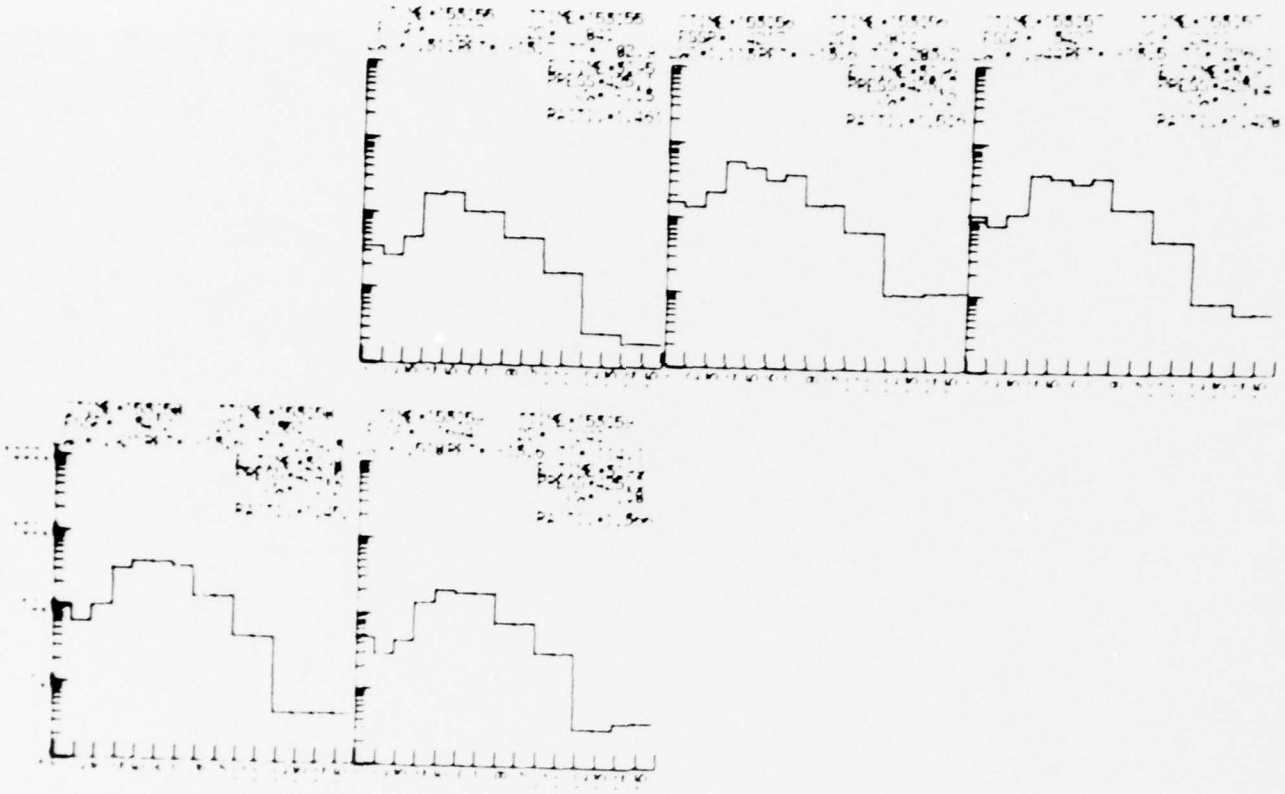


FIGURE 11. SAMPLE OF FSSP CLOUD DROPLET SPECTRA FOR A PORTION OF A T-28 CLOUD PENETRATION IN FLORIDA ON 13 AUGUST 1978. EACH HISTOGRAM REPRESENTS THE SPECTRUM OBSERVED DURING A 1-SEC SAMPLING PERIOD. THE ABSCISSA REPRESENTS DROPLET SIZE CHANNELS IN 3 μM DIAMETER INCREMENTS BEGINNING WITH 3 μM. THE ORDINATE REPRESENTS NUMBER CONCENTRATION (LOG SCALE) FOR EACH CHANNEL IN CM^{-3}. THE LEGEND WITH EACH HISTOGRAM CONTAINS A VARIETY OF RELATED INFORMATION.

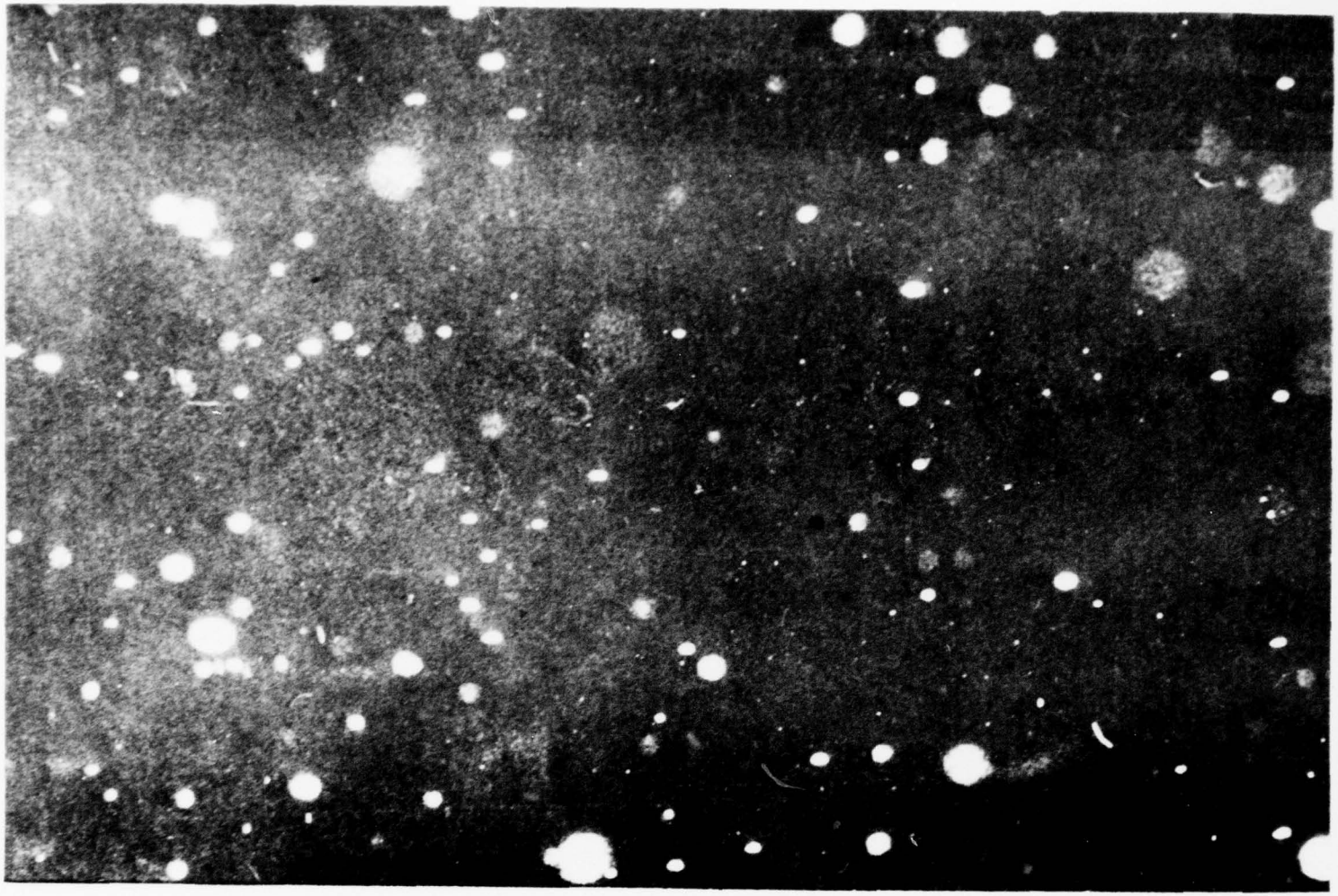


FIGURE 12. SAMPLE OF CANNON PARTICLE CAMERA IMAGES FROM A T-28 PENETRATION IN FLORIDA ON 9 AUGUST 1978. MOST OF THE PARTICLES VISIBLE ARE RAINDROPS (AS INDICATED BY THE DOT PAIRS) 1-2 MM IN DIAMETER, AND THEIR CONCENTRATION IS ABOUT 9000/^{3}. THE VOLUME IN FOCUS IS ABOUT 10 LITERS.

Future plans for the T-28 system call for instrumenting the airplane to take measurements of the electrical conditions in the storm cells; redesigning the primary instrumentation system to include an on-board microprocessor which will allow data to be collected more efficiently and at a higher frequency; and installation of a flight test boom to give angle of yaw and more accurate angle-of-attack information.

In summary, the T-28 is a unique research platform for providing information about the interior characteristics of thunderstorms and hailstorms. Its full potential has yet to be reached. If you are interested in the use of the T-28 for any project or program, please feel free me at the IAS or Dr. Arnett S. Dennis, Director of the IAS.



TRAINING
COMMITTEE

SECTION VI

SUMMARY REPORTS

OF THE FIXED COMMITTEES

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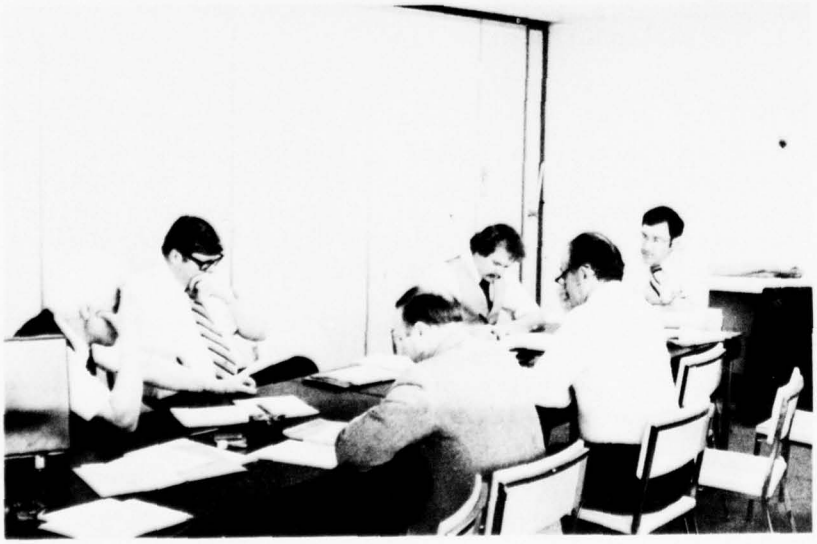
FLIGHT
OPERATIONS
COMMITTEE



ACCIDENT
INVESTIGATION
COMMITTEE

AIR
TRAFFIC
CONTROL
COMMITTEE





AIRPORTS
COMMITTEE

SUMMARY REPORT: TRAINING COMMITTEE

Grant C. Beutler

United Airlines Flight Training Center

Members: Grant C. Beutler, Chairman; United Airlines
John H. Bliss, Flying Tiger Line
John R. Colomy, St. Cloud State University
Don S. Cornwall, Air Line Pilots Association
William Critch, Boeing Commercial Airplane Company
Richard D. Gless, AOPA Safety Foundation
George R. Hammond, USAF 12th Weather Squadron
Louis Ludwig, FAA General Aviation Division
Loyd C. Parker, NASA Wallops Flight Center

Several needs emerged from the interactions between the Training Committee and the floating committees. Frequently these needs were felt more acutely by either the general aviation community or the commercial/military community. The differences in their equipment, operating environment, training resources, and governmental regulation create differences in the training challenges faced by each.

A common problem which recurred was the difficulty experienced in teaching airmen to understand and use the resources available for reporting and forecasting weather conditions.

The committee learned that a sophisticated communications system utilizing CRT's is being designed and will be installed for widespread use in the next few years. The system will disseminate weather information now issued by conventional means.

Recommendations

1. Use a Systems Approach in implementing the new communication system. Included in this task should be an effort to standardize the symbology presently used to depict weather information. Consistency in depicting given phenomena from one type of display to another would be considered a virtue.

2. Include Computer Assisted Instruction (CAI) as an integral part of the design in any automated system. Such a system would allow the user to reference explanatory material to refresh his memory or briefing materials in areas where doubt exists. This mode should be easily accessed to enhance utility.

Winds and Wind Shear

There was some conflict on how best to teach the phenomenon of wind shear. The dilemma of whether to teach extensive *theory* or simply *recognition and procedures* has not yet been resolved. The consensus was that the phenomenon can be defined and understood and that an engineering solution can be found to more effectively cope with the problem.

One airline captain underscored the inadequacy of existing procedures for coping with the wind shear problem. He recommended the method of selecting appropriate ground speed and minimum airspeed values considering surface wind values. An approach can then be successfully completed by keeping both speeds above appropriate minimum values.

Another airline captain stated that he has been adequately exposed to theory through company training, but he feels there is a need for more precise definition of approach and takeoff area conditions upon which operating decisions can be based.

Recommendations

1. Research and develop methods of forecasting and detecting wind shear, especially in the areas of approaches to runways. Present methods do not provide precise enough information in these areas.

2. Mail FAA Advisory Circular 00-02A (Advisory Circular Check List) to all newly certificated airmen.

A number of FAA information and training materials exist (video tapes, films, printed material) and are available. Advisory Circular AC 00-50A (Wind Shear) has been recently published. Some airmen are not aware of the existence of these materials.

Atmospheric Electricity and Lightning

Discussion centered around tendency for pilots to accept communication problems as simply a characteristic of the system. Many problems can be traced to inadequately maintained pitot-static (p-static) bleed devices and associated malfunction.

Recommendation

Adequately train pilots, as well as maintenance and electronic repair personnel, in the importance of p-static bleed devices and the effect of faulty equipment on radio performance.

Icing and Frost/Turbulence

In discussions with both of these committees, two problems emerged. The first was the lack of precision in forecasting techniques and the second was the lack of flight training in actual adverse conditions.

Recommendations

1. Continue research into methods of accurately forecasting conditions of icing and turbulence.

2. Encourage flight schools and flight instructors of the FAA and the general aviation industry associations to provide flight training in actual Instrument Meteorological Conditions (IMC) whenever possible and appropriate to do so.

3. Encourage industry to develop a low-cost flight simulator capable of realistic simulation of trubulence, effects of induction system and structural icing and low ceiling/visibility conditions. When this new generation of simulators becomes available, flight schools should develop syllabi and training scenarios to afford the most effective use thereof.

Finally, it was recognized that ultimately the individual pilot is responsible for himself. The finest equipment, the most elegant communications systems, the most reliable reporting and forecasting systems cannot compensate for negligence on the part of the pilot. Unless he uses the resources available, nothing will be efficacious.

SUMMARY REPORT: FLIGHT OPERATIONS COMMITTEE

James M. Dunkel

Federal Express Corporation

Members: James M. Dunkel, Chairman; Federal Express Corporation
Dale Istwan, Air Line Pilots Association
Max Karant, Aircraft Owners and Pilots Association
Richard L. Kurkowski, NASA Ames Research Center
Loren J. Spencer, FAA
Joseph W. Stickle, NASA Langley Research Center

At this workshop all the committee members found themselves reviewing many of the same problems that had been discussed at previous workshops on this subject. This is not to say that improvements have not been made, but rather that specific recommendations and commitments are necessary for more rapid improvements.

The Flight Operations Committee met with five floating committees in order to understand the current state and limits of technology in each area, review new developments, and communicate those areas of concern as they dealt with Flight Operations. The discussions with the floating committees are given below.

Atmospheric Electricity and Lightning

The committees discussed the current inability to identify the atmospheric conditions which would allow specific forecasting of these occurrences in a timely manner. All efforts in this field to date have been in the development of ground-based units only. We felt that if this trend continued, it would be necessary for the developers to address five basic concerns:

- Timeliness of reporting (real-time vs. delayed reporting)
- Standardization of communication (terminology)
- Quantity of information required
- Accessability of information to general aviation
- Detection and range potential and actual atmospheric conditions

Both committees agreed that it was necessary for a central data base to be established in order to track lightning strikes to aircraft. It was felt that a majority of this information is currently available in some form, but is not always freely disclosed. Researchers may establish this data base of information for large aircraft from:

- Commercial airlines
- Manufacturers
- Government agencies

and for general aviation aircraft from:

- Repair facilities
- Commuter airlines
- Government agencies

In all likelihood, sources must be held in confidence to insure total participation.

Fog, Visibility and Ceilings

The aviation community has long recognized the increasing burden which has been placed on the NWS to forecast meteorological conditions. Currently, it is responsible for the aviation, maritime, agriculture and tourism communication. Although the expected responsiveness has increased drastically, the available resources have not kept pace.

Discussions pointed out that this dilution of resources has caused more generalization of meteorological conditions in forecasting for the aviation industry, which has required a greater degree of preciseness. The commercial airlines have recognized this over the years and have therefore established meteorological departments. In addition, it is apparent the FAA has many of the same concerns because it currently employs meteorologists to support its controllers.

Technology has made great strides in developing automated sensing and reporting stations for each airport. These stations will allow more timely dissemination of current conditions, because measurements will be made and reported every minute rather than three times an hour as is the case today.

Standardization of data is currently one of the largest problems which must be tackled, and improvements are still pending in the following areas which have been discussed at previous workshops:

- Standardization of measurement from FAX charts to termina. weather reports.
- Specific standards and accountability for aviation forecasts
- Standardized training and proficiency checks for new and current pilots, dealing with terminology and available reports.

The following recommendations were presented to the group:

- That the airlines join together for centralized meteorological needs. This may seem farfetched, but due to the increasing costs of maintaining their own meteorological departments, it is becoming a serious consideration.
- That the aviation community petition the NWS for more support.
- That the Congress be made aware of the continued decline of forecasting services and be presented with these recommendations as possible solutions:
  - Reevaluate priorities of the NWS resources.
  - Investigate the feasibility of FSS reporting to the FAA to gain accountability.

Turbulence

Discussion on this subject was basically broken down into two areas:

- Wake turbulence
- Clear air turbulence (CAT)

Of the two, greater advancements have been made in the area of measuring wake turbulence. Twelve airports in the United States currently have measuring equipment, and this number is to be expanded to twenty-four within six years.

When dealing with CAT, however, we found that long-range forecasting is currently almost impossible and that real-time reporting and anticipating are weak. A review of several systems was given by representative groups, e.g., NASA's test with Bendix utilizing water vapor and Doppler's ground-based radar to detect tornados and degree of turbulence within a storm.

Our committee felt that improvement of our reporting systems and gathering techniques would be a good interim step. This would involve the use of SIGMETS and PIREPS by 1) plotting them on a map, 2) tracking them, and 3) setting specific guidelines for getting standardized and timely reports back to the pilot.

Winds and Wind Shear

Wind shear detection units, which are keyed by any variation of +15 knots, have now been installed at seven major airports; and the installation of these units in other U.S. airports is progressing. However, manufacturers, as well as the FAA, have been called on to determine specific actions to be taken after detection relative to aircraft limitations and compensative maneuvers to be made by crew members.

The major problems in dealing with winds aloft were summarized by the Flight Operations Committee as:

- Inadequate reporting by the NWS (12-hour reports).
- Inaccurate forecasting below 12 feet, mostly due to terrain changes.
- Lack of updates on a real-time or exception basis.

Our recommendations to increase our winds aloft reporting accuracy are:

- Direct input to and from Center to the aircraft to update and report actual winds aloft.
- Plot actual winds aloft in the same manner as forecast winds (from the PIREPS). This would make the necessary briefing information available to general aviation.
- Increase the number of soundings made by the NWS back to four times per day.

Icing and Frost

Of all the weather phenomenon reviewed, this area drew the most discussion. To date, all large aircraft have operating limitations based on type and amount of frozen precipitation. They are exact as to the weight penalties, but they give no guidelines with regard to wet vs. dry snow or where measurements should be taken on a runway. Flight Service does not presently have adequate measuring techniques for reporting wet vs. dry snow. The FAA, in conjunction with aircraft manufacturers, commercial operators, and the NWS, should establish these measurement criteria and reporting procedures.

It was reported that SAAB has developed and is marketing a breaking measuring device which measures the coefficient of friction. If this device is proven functional, it should enable standardization of breaking action reports which will enable each aircraft manufacturer to develop the performance charts required.

Our discussion of icing conditions brought forth the concerns of both rotorcraft and general aviation participants. NASA and several other groups are developing and testing anti-ice and icing effects on rotorcraft. The committee felt that the manufacturers must define the icing envelope of the aircraft with and without icing protection. The NWS must insure its reporting system can be correlated to the manufacturer's specifications (i.e., standardization). More research in the areas of on-board measuring devices and investigation of regulatory reform dealing with such operations is required.

General aviation suffers a twofold problem:

- The weight penalties on the aircraft resulting from installation of ice equipment.
- Cost of installation of such equipment.

Since the performance penalties to general aviation aircraft are so great, the committee asks that NASA, in their development of rotorcraft protection, keep in mind that the same requirement of a lightweight, low-cost, low-power system is also required by general aviation.

Conclusions

We noted three major areas of common concern throughout our interfaces. Industry as a whole has made great strides in technology, but must concentrate on these three areas:

- Create *real-time* meteorological support and safety systems.
- Improve communications among the aviation community to solve problems and to meet our real-time requirements.
- Improve training by:
  - Identifying requirements for all users' and producers' meteorological information.
  - Standardizing requirements for pilot weather training.

Key factors necessary to accomplish these goals are:

- Standard terminology
- Documentation
- Coordination by all parts of industry to interrelate activities in a spirit of cooperation.

SUMMARY REPORT: ACCIDENT INVESTIGATION COMMITTEE

Charles L. Pocock

U.S. Air Force Safety Center

Members: Charles L. Pocock, Chairman; U.S. Air Force Safety Center
Peter Chesney, FAA Flight Standard Service
H. Prater Hogue, International Society of Air Safety Investigators
Lester R. Kerfoot, Jr., System Safety Associates, Ltd.
Russell S. Lawton, AOPA Operations and Safety
William Melvin, Air Line Pilots Association
Huard H. Norton, FAA Accident Prevention Staff
Andy D. Yates, Jr., Air Line Pilot Association

The fixed committee on accident investigation had a variety of pilots and, more particularly, a variety of accident investigators. Military, commercial, private and regulatory interests were represented. A variety of subjects were discussed. This report covers two types of subjects: First, there were overview topics, or topics of a general interest to one or more of the rotating groups. Second, there were more specific topics which were discussed in depth with one of the specialized groups.

GENERAL SUBJECTS

Human factors were discussed as causal in aircraft accidents. The investigation group believed that secondary cause factors, which are the real why's, are often not addressed, probably due to inadequate investigation. The fact that a pilot attempted to fly VFR in instrument conditions is only a result of some other true cause of the accident. What we need to know is why did the pilot try to do that? Was it inadequate training? inadequate preparation? inadequate briefing? get-home-itis? or some other reason why he allowed himself to get into the accident-producing situation? Further, once the VFR pilot realized he was getting into instrument conditions which he was not qualified to handle, why didn't he alter course to avoid the weather or turn around and return to his departure point?

The investigation committee felt that wrong causal agents are occasionally attached to accidents because of lack of thorough human factors investigation, and this is a major problem. It is incumbent upon all of us who participate in accident investigations to make sure that we arrive at the true cause of each accident.

Density altitude was discussed and the conclusion was that it is still a hidden killer. There are two problems associated with high density altitude. First is the lack of reporting, and second is the lack of pilot understanding about aircraft performance degradation in high density altitudes. Several approaches were considered as recommendations. One might be that in designated mountainous areas, density altitudes which are more than 1,000 feet above field elevation should be reported on sequence reports. This is only a possible suggestion, not a studied recommendation. The group felt that there needs to be a more positive way to insure high density altitude information is available to the pilot. High density altitude presents the inbound pilot certain problems, but more importantly, the departing pilot must know how his aircraft is affected prior to committing for takeoff.

The lack of weather information. Many aircraft accident investigators lack the necessary meteorological information to form valid findings and recommendations about a specific accident. In some cases the information is not available. In other cases investigators fail to use all sources available. Determination of the exact weather conditions at the time and place of the accident is important. If the accident occurs at an airport, special airport observations are usually available; however, if the accident occurs off the airport, investigators may have to go to other sources in order to assemble the accident weather picture. The destination airport may take a special observation when they discover an airplane is missing. However, there are also many other sources in federal, state and local governments as well as private concerns observing weather on a frequent basis. The problem is there is no centralized listing of all these agencies. The investigation group felt that a need exists for an up-to-date, consolidated listing of weather observing stations--not a listing that every investigator carries with him, but a centralized location which can be called for a listing of the agency names and telephone numbers of weather observing stations within a certain radius of an accident location. Also there is a need for a better method of retrieving *all* pertinent and often perishable data such as satellite pictures, local observations and automatic observations. In a large scale investigation, investigating meteorologists generally do this, but in the smaller investigations data gathering is often difficult or very time consuming.

Automatic Observing and Reporting Stations need to be time-coordinated and identified. The group also felt that data collected from these stations needs to be retained for some specified time in a retrievable manner.

Pilot perception of what the weather actually is from the presentation of the weather information seems to be a problem. The investigation group felt that sequence reports, NOTAMS, PIREPS and verbal briefings need to be more clearly understood by the pilot. This may seem obvious, but is really quite a difficult problem. Some suggestions to increase understandability include: Considering our increased transmission capability, perhaps the airport name instead of the three-letter identifier should be used on sequence reports. Severe weather conditions should be

in plain language instead of symbology. Briefings, particularly telephonic briefings where the briefer does not have eye contact with the receiver, must be slow and understandable and there must be several opportunities for questions.

Closing the gap between accident investigation and prevention, and also between research and prevention, is a continuing problem. Short, simple, readily-understood articles by experts are always needed by editors of aviation magazines. For example, John Prodan could write an article on his T-28 encounters with thunderstorms, M. P. Amason could write an excellent article on the effects of lightning on aircraft, or John Houbolt could write an article on turbulence encounters and structural problems with a general aviation aircraft. Simple articles written by people of that caliber for a magazine such as AOPA's *Pilot* would certainly be in demand. There is a need and a challenge to each of us to talk to pilots in simple language and tell them what we are really doing.

ROTATING COMMITTEES

All rotating committees had a great deal of interest in Flight Data Recorders (FDR's) which are used by the accident investigator to recreate the conditions at the time of the accident. It is important to know that there are limitations and inaccuracies in the recorders. The recorded information is often taken from coarse instrumentation and then attempts are made to make fine readings, which just can't be done with accuracy. We discussed the need for better recorder maintenance by the airlines. Often investigators arrive at an accident and find that either the recorder itself is inoperative or some of the desired parameters were not being recorded. Additionally, there are some problems with many of the international carriers who calibrate their own recorders instead of returning them to the manufacturer.. Flight data recorders are delicate instruments that have to be calibrated with a great deal of accuracy and many people are not doing this.

There is a need for better recorder protection. Recorder crash protection criteria should be reviewed. Certainly recorders will be required for any fly-by-wire aircraft. The post crash investigation of a flight control mishap on a flight-by-wire aircraft is next to impossible using conventional techniques.

Fog, Visibility and Ceilings Committee

Slant range visibility sensors were discussed and it was concluded that while it would be very desirable to have slant range visibility information in the cockpit, problems in development and associated costs may not be worth the investment. Ceilometers in the approach zone were also discussed along with the eye hazards associated with light-emitting instruments. The value of RVR trend data was discussed, and it was generally agreed that trend information would be valuable,

however, the system needs extensive testing and verification before adoption. There are problems with reliability of a developing trend and there may be a tendency to commit to a trend. That is, a pilot might descend from altitude in preparation for an approach based on an improving RVR trend, and then when arriving at minimums discover that the trend did not materialize and now his alternate options may be jeopardized. There is a problem in the timeliness of observed weather information and PIREP information being transmitted to the cockpit. This is a continuing problem and efforts to reduce the time should continue.

Turbulence Committee

Generally, discussions with the Turbulence Committee were confined to clear air turbulence (CAT) and gust overload turbulence. Wind shear discussions were held for the Winds and Wind Shear Committee. The joint committees reviewed in some detail CAT warning systems currently being tested and developed. We talked about these systems in terms of the timeliness and reliability of the warning and how this varies with altitude. The requirement for 6-7 minute warning is valid to insure that meal service can be terminated, trays and carts secured and a seat belt check completed. At certain altitudes only a 4-5 minute warning is possible.

Design gust criteria was discussed. It was generally agreed that present criteria will be used for the Boeing 757 and Boeing 767. Present criteria has proven adequate from a safety standpoint in previous designs.

There was a discussion of best turbulence penetration air speeds and the groups generally agreed that this is not a problem today.

Winds and Wind Shear Committee

The joint committees concluded that perhaps too much attention is currently being placed on the gust front condition and not enough emphasis on the area immediately below the thunderstorm, in the cold air outflow region. Other areas may also have been neglected such as frontal zones and low level jet stream conditions. The committees discussed shear conditions in the pre-tornado cyclonic cloud and the hazards to aircraft in this region. This large swirling area, which often spawns a tornado, has certain peculiar hazards which are little known and not broadly understood. Finally, the committees agreed that there is an urgent need for standardized, universally understood wind shear terminology.

Icing and Frost Committee

The joint committees held rather lengthy and detailed discussions. The present frost research was discussed and it was agreed that there is a need for similar research on the effects of rain on aircraft

performance. Runway rain, snow and slush contamination hazards were discussed, particularly the hazards to takeoff performance degradation; stopping performance; engine flameouts; and frozen landing gear, flap and flight-control components when impacted by slush or water. Induction icing in reciprocating and turbine engine aircraft was also discussed. In the area of structural icing it was agreed that there seems to be a movement away from deicing systems on larger aircraft. There was a lengthy discussion about the difficulty of investigating an ice encounter mishap. In a post crash environment, ice has generally melted naturally or melted by post crash fire. There was a brief discussion about runway snow and ice removal. The research being done in Canada, particularly the air blast snow removal system, was discussed. The differences between FAA requirements and Military Specifications requirements for engine water ingestion were discussed.

Atmospheric Electricity and Lightning Committee

An enlightening discussion of atmospheric electricity led to talks about problems with the totally fly-by-wire aircraft. This is a problem in military aircraft *now*, but it is several years away in civil aircraft. Anticipated problems of post crash investigation with fly-by-wire aircraft were also discussed. We also talked about the poor conductivity of composite structural material and attendant lightning problems in aircraft usage.

SUMMARY REPORT: AIR TRAFFIC CONTROL COMMITTEE

Frederick M. Stone

U. S. Air Force/AFCS

Members: Frederick M. Stone, Chairman; USAF/AFCS
John P. Allen, Professional Air Traffic Control Organization
James R. Banks, Air Traffic Controllers Association
C. L. Chandler, Delta Airlines Flight Control
A. Charley McTee, Bunker Ramo
Robert Mudge, Air Line Pilots Association
William A. R. Robertson, Air Line Pilots Association
W. Don Wood, Atlanta Air Route Traffic Control Center

During the introductory phase, the Air Traffic Control Committee noted most of the discussion topics were frequently associated with severe weather, i.e., turbulence, wind shear, lightning, and icing. They also noted the reliability of predicting these phenomena, both in intensity and precise location, are considered suspect by much of the flying community. Thus, while most pilots are aware of the potential consequences of flying into an area of forecast severe weather, they continue to do so because they do not believe the forecast to be accurate enough to alter their proposed route of flight. Predictably, pilots find themselves operating in weather conditions neither they nor their aircraft are capable of handling. Such situations impact the Air Traffic Control System, forcing controllers to operate in a reactive rather than a planned air traffic control environment. Emergency or near emergency situations develop, aircraft are rerouted in flight, airborne delays and traffic congestion develop, controllers and pilots are taxed to the limits of their abilities--sometimes beyond--and, at the extreme, there are needless tragic accidents. It is the committee's opinion such crisis situations can be avoided through the development of better guidance for aircrews and more precise methods of forecasting/detecting adverse weather conditions.

Having identified a root problem in nearly every topic, the committee turned its attention to wind shear as it affects Air Traffic Control and the people they serve, the pilots.

WIND SHEAR

Problem Area

A major problem with wind shear is the inability to accurately predict/detect its presence. Consequently, areas of forecast wind shear are made unnecessarily large as a form of insurance. The practice of forecasting an area of wind shear larger than actually exists denies the controller valuable airspace for use in vectoring aircraft and places the pilot in the position of either landing in an area of forecast wind shear, suspected by the pilot to be unnecessarily large, and violating company policy, or avoiding the area altogether and not completing the mission. Added to the problem is the pressure of the pilot's prior knowledge of wind shear in a particular area and/or his (companies') knowledge that, while he is (contemplating) diverting to an alternate airfield, other aircraft are landing at the airport in the area of forecast shear.

Research Required

To improve wind shear detection/forecasting and pilot response thereto:

- Emphasis should continue on development of airborne and ground-based wind shear detection equipment capable of actually detecting and accurately predicting the parameters, intensity, and direction of movement of wind shear systems. Airborne equipment must provide sufficient advance notice to allow passengers and crew members to return to their seats and fasten seatbelts and the pilot enough time to alter the route of flight or establish the appropriate wind shear penetration airspeed/configuration. Ground-based detection systems must be able to detect wind shear along the approach to and departure from the runway, and at altitude to support the en route Air Traffic Control System.

- Based on the improved ability to detect and predict wind shear, the criteria for defining areas of forecast wind shear should be revised to eliminate the "insurance" factor which currently denies controllers and pilots valuable airspace. The criteria must incorporate the dynamics of wind shear systems, i.e., system movement and intensity, on a real time basis.

- Research should be conducted to determine how close an aircraft can fly to a wind shear without actually becoming involved in it. At the same time, research should continue to determine the intensity of wind shear an aircraft (by type) can withstand if it actually penetrates a system. Such information is invaluable to the controller (and pilot) in planning traffic flow.

Information Transfer Mechanism

Conventional radio communication systems limit the information transfer between pilot and controller and impact the volume of traffic handled by the controller. As it becomes necessary for controllers to provide more information to each aircraft, the number of aircraft they are able to control is reduced due to air-to-ground frequency saturation and the diversion of a controller's attention from the control of aircraft to interpreting and relaying weather information. A possible alternative would be transfer of the wind shear information on a real time basis using a data link system and a visual display in the cockpit and air traffic facilities. In exploring such alternatives, a human factor study should be conducted to insure pilots and controllers are not being provided more information than can be absorbed at a given time; i.e., continuously updated weather display in addition to other information already in the cockpit/control room.

Format

Wind shear intensity should be reduced to a numerical value. A pilot could then use the value to determine if the intensity of the system is too great for his type aircraft to penetrate. Again, the system would have to be presented as a dynamic real-time value; i.e., current intensity as well as a continually updated history of the system.

Aviation Safety

Few, if any, pilots would knowingly penetrate a strong wind shear system. However, since most pilots seldom experience wind shear to the degree forecasted, they are tempted to fly through an area of forecast shear rather than around it if the alternate routing represents a significant change to their original flight. Given that the equipment recommended can be developed and placed in service, an intensive information program should be undertaken to make the pilots and controllers aware that when a wind shear is forecasted/detected, the chance of its actually existing in the precise area forecasted is nearly 100 percent and steps must be taken to avoid it.

ATMOSPHERIC ELECTRICITY AND LIGHTNING

Problem Areas

- Lightning strikes pose some serious problems for aircraft and for ground-based elements for the Air Traffic Control System. With increased reliance on computer processing in both aircraft and ATC elements, susceptibility of these computers and their power sources to the voltages and currents induced by lightning must be eliminated. Neither the aircraft nor the Air Traffic Control System can tolerate a sudden and total computer outage. The loss of a NAVAID to a lightning strike may also have severe consequences.

- Lightning effects on structures of composite materials, or metallic structures with composite sections, require designer attention to problems of bonding and continuity of shielding. A major problem is the present lack of in-depth flight experience with structures of this type, as well as with the digital avionic systems which are being introduced.

- The negative effect of nearby lightning strikes on pilots also must be considered--two of these effects which deserve mention are (1) up to several seconds of flash blindness which may result from a nearby bolt; and (2) a general pilot distaste for things which go flash-bang around his airplane.

- Radio noise ("static") induced by lightning has the negative effect of disrupting communications between pilot and controller, increasing the likelihood of an error in this link.

Research Required

- *What is known*. Lightning, as a phenomenon, is reasonably well understood; parameters (current, duration, etc.) of typical strikes are known. In part, because of this high degree of knowledge, present aircraft manufacturing technologies offer a high degree of lightning protection. These technologies do not, however, appear to have been fully applied to the construction of ground systems, including the computers which serve the ATC system. Considerable study of systems which are resistant to electromagnetic pulse (EMP) effects has been conducted for nuclear hardening, and this technology may be directly applicable to "lightning hardening" of both ground and airborne systems.

- *What is needed*. Pilots, in general, prefer to avoid lightning, not so much for itself as for the thunderstorms with which it is often associated. Improved forecasting of lightning areas is a desirable goal to aid this avoidance. A specific desirable item for ground installations is a system which can warn of an impending strike in time for activation of standby systems, or protection of primary ones. A composite "hazard warning" system, providing alerts for dangerous lightning, turbulence, precipitation, and wind shear conditions would be desirable, although difficult to achieve.

The correlation of lightning with other meteorological phenomena (turbulence, wind shear) is desirable. Since lightning is a highly observable (visually, electrically or sonically) event, it would serve as a "flag" for less observable conditions if a correlation could be established.

Research and development should continue in defining "lightning hardened" designs for (1) avionics; (2) ground computer, communications, and NAVAID installations; and (3) composite structures.

Information Transfer

- *Information sources.* Since the lightning precedes the thunder, forecasts of thundershower/thunderstorm areas also predict lightning. Except for this association, forecasting of lightning is difficult, with ground-based sensor nets useful in establishing strike danger in defined areas. PIREPS, weather observations, and electronic detection of sferics are potential means of detecting active lightning areas.

- *Information transfer mechanisms.* Pilots receive some information on potential lightning areas with their preflight weather briefing, which should include SIGMET information as of the time of the briefing. In-flight weather advisories, including those for lightning, are transmitted via the controller-to-pilot link. PIREPS also are transmitted, if significant, from pilot to pilot via the controller.

- *Stumbling blocks.* In areas involving transmission of weather and flight information, the communication links which involve the controller are the weak parts of the system because of high controller workload. This workload increases drastically in the very periods of adverse weather, poor visibility and heavy traffic which demand maximum efficiency from the communication link. Lightning advisories are less affected by these overloads because lightning is avoided not so much for itself, as for the thunderstorms with which it is normally associated; and, presumably, the thunderstorm will take precedence.

Format.

There were no recommended changes to the format used to indicate lightning. Neither were there any suggested changes to improve aviation safety other than those previously mentioned.

FOG, VISIBILITY AND CEILINGS

Problem Area

To the pilot and controller, the greatest constraints to day-to-day flying are restrictions to visibility; i.e., clouds, fog, smoke and glare. When added to the present mix of aircraft, both groups wonder if today's minimums are realistic. In today's environment, closure rates exceed human capabilities to see potential traffic conflicts and react in time to avoid a mid-air collision. Although a basic pilot/controller tenet is to "see and avoid," the concept is no longer a viable method to apply separation to certain categories of aircraft or during sky conditions which adversely affect timely acquisition of all aircraft; i.e., controlled and uncontrolled areas wherein Mach I speeds are mixed with 100 mph aircraft operating legally with

one mile visibility. Visibility is also a problem at many locations where the only weather information available with which the pilot makes his decision to fly under VFR is that which he observes from the ramp. At still other locations where forecasters are assigned, their limited numbers frequently make it impossible for pilots/controllers to obtain timely, quality weather information, particularly during rapidly changing weather conditions. Such deficiencies seriously impact Air Traffic Control operations in the busier terminal areas. Finally, pilots and controllers are continually confronted with the decision of whether or not to continue VFR operations when sky conditions are reported as VFR but when cockpit or control tower visibility is limited by haze, smoke or glare. Simply stated, are present VFR criteria realistic in view of today's traffic mix? How can pilots and controllers obtain current, accurate weather information upon which to base their decisions? And what can be done to report visibility which is actually seen by the pilot and controller?

Research Required

There is a need to review "visual" criteria. As applied to VFR, visual approaches and their various applications, does a ceiling of 1,000 feet and a visibility of three miles represent a viable methodology for separating present generation aircraft? The review should consider (1) the genesis of VFR criteria; (2) current air traffic conditions as related to modern speeds, closure rates, low profiles, reduced visibility over congested areas (yet above basic VFR); and (3) both controlled and uncontrolled areas where Mach I speeds are mixed with 100 mph aircraft operating legally under one mile visibility.

Initiatives have been taken in a National Weather Service-sponsored FAA procurement of approximately 900 self-contained weather measuring devices for use at small, otherwise unattended airports. These devices will provide a continuous automated readout of ceiling and visibility at an approximate cost of between 60 and 70 thousand dollars each. Tentative procurement time frame is 1981. Because of the review processes attendant to final program acceptance, this program must be considered tentative. However, the tentative categorization does not obviate the need for unattended airports to be provided with accurate measuring devices.

Having recognized a problem in obtaining quality terminal forecasts, particularly when the airport weather approaches or is going below established minimums, there appears to be a requirement for additional observers/forecasters to amend, update, and otherwise provide timely information which reflects rapidly changing weather conditions. It is unlikely such additional manning would be made available without a study to support the need for the additional forecasters.

Perhaps the most difficult problem to solve, yet a most pressing need, is to reassess and revalidate visibility and the realistic effects its various applications have on aviation safety; i.e., the glare problem

and the inability to readily identify traffic during haze and smog but in a legal VFR environment.

Information Transfer

- *Information sources.* Weather measuring equipment, PIREPS, weather observer and control tower observations are the principle sources of weather information.

- *Transfer mechanism.* A variety of transfer mechanisms are employed in relaying information to the pilot and controller; i.e., telephone, telautograph, closed circuit television (CCTV), air-to-ground radio, digital RVR equipment, etc. While these transfer methods are satisfactory under most weather conditions, most do not satisfy the requirement for timely information during rapidly changing weather conditions.

- *Stumbling blocks.* Weather information, particularly visibility, is extremely perishable. As such, the transfer mechanism becomes all important and is the element which is most frequently criticized during rapidly changing weather situations. Pilots are concentrating on their instruments, tower controllers are directing their attention to an air traffic environment made worse by poor visibility, and forecasters/observers--already working at capacity--are unable to keep pace with rapidly changing weather situations. Thus, the number of meaningful weather observations decreases at the time they are most needed. Coupled with this are the relatively slow methods of relaying the information; i.e., transposing observations onto a telautograph and relaying data from the telautograph to the pilot. A faster, more accurate method of relaying information would be through use of a data link from the equipment/observer directly to the pilot and controller. This would reduce controller workload and air-to-ground frequency congestion. It may, however, present too much information in the cockpit. As well, the expense would likely be prohibitive to general aviation pilots.

Format

The need for standardization in reporting weather information is apparent. The use of statute miles and nautical miles, octaves and tenths, millibars and inches of mercury, etc, is, at the very least, time-consuming to transpose to something useable to the pilot and compromises flying safety. The subject of a standardized format should be addressed on a worldwide basis through ICAO.

Aviation Safety

The hazards of operating "legally" under VFR during periods when visibility from the cockpit or control tower is less than that required for VFR should be stressed during pilot and controller training.

ICING AND FROST

Problem Area

Icing and frost pose a different kind of problem. While the other topics address a potentially dangerous environment in which an aircraft is flying, icing and frost are a threat to the pilot because they accumulate *on the aircraft*. Furthermore, they accumulate in such an insidious manner the pilot is frequently not aware of their presence until the problem has become serious. This is particularly true of large jet aircraft where the wing surfaces are not easily visible from the cockpit. Although there has been extensive study on the effects of icing and frost on fixed-wing propeller-driven aircraft, relatively little study has been conducted on jet aircraft, the logic being that since jet aircraft have a high rate of climb and cruise at much higher altitudes, they are only briefly exposed to weather capable of producing ice. During such periods, the only areas requiring anti-ice protection are the engines and, on some large jets, the leading edges of the tail. The lack of study of the effects of icing and frost on jet aircraft appears a serious shortfall which should be corrected, for while jets do have a high rate of climb and normally cruise above the weather, there are several situations during which jet aircraft may be exposed to icing for extended periods of time. For example, holding is normally performed at lower altitudes and indicated airspeeds and in a nose high altitude which exposes a larger cross section of the aircraft to the effects of icing. Additionally, super-cooled fuel in the aircraft wings causes ice/frost to form on the wings as aircraft descend from high altitudes through visible moisture at the lower altitudes. The inability to accurately forecast/detect icing frequently results in the controller first being notified of its presence through a PIREP. Such PIREPS from pilots operating in one or more holding patterns in a high density terminal area results in a traffic flow realignment and the establishment of new landing priorities, reactions which could be avoided if areas of icing were known in advance.

There is a general lack of controller knowledge regarding the effects aircraft anti-icing systems have on an aircraft descent profile. Consequently, jet aircraft using their anti-ice system frequently have difficulty complying with ATC descent instructions because of the higher power setting required to support the anti-ice system. Finally, there appears to be little information on the effects of frost on large jet aircraft on takeoff. Such information would assist the pilot in determining the amount of frost, if any, which is acceptable for takeoff.

Research Required

- *What is known.* Pilots are aware of what anti-icing capabilities are available in their aircraft and, through experience, have some idea of what type of icing their aircraft can tolerate. They alone are aware of when their anti-ice systems are

in use. This information should be made available to the controller to allow adjustment of traffic flow/pattern accordingly.

The conditions which produce icing are well known by forecasters and the general areas where icing may occur can be predicted.

What is needed. Because many of the previous indicators of icing are not as easily observed from the cockpit of jet aircraft, research and development of an airborne device which will indicate the probability of icing, as well as an actual ice detector device, should be undertaken.

A general study to determine the operating characteristics of jet aircraft under icing and frost conditions should be made. Additional studies should be made to identify characteristics peculiar to each type aircraft. Research should continue in the design of ground-based equipment which will accurately locate areas of icing.

Information Transfer Mechanism

As a near-term solution, pilots should advise the controller of the anti-icing capabilities of the aircraft, when the system is in use, and, if necessary, what intensity icing can(is) affect(ing) their aircraft. A long-term solution would be development of an aircraft transponder link to the airborne ice detection device which would indicate by alphanumeric symbol on the controller's scope when an aircraft is encountering icing which is beyond the aircraft's systems ability to handle.

Format

If the long-term solution is adopted, the symbol in Field E of the alphanumeric data block could be used to indicate the presence of icing.

Organizations Identified for Research/Development

FAA - To provide current available information from pilots to controllers on the effects of icing/anti-ice systems on aircraft performance.

NASA/NOAA - Development of the airborne detection device.

FAA/Manufacturers - Research on icing effects on aircraft.

FAA - Link ice detection device to transponder for transmission to controller's data block.

Aviation Safety

As mentioned, information on aircraft performance as it is affected by icing or an anti-ice system must be made available to the controller. Pilots must make the controller aware of changes in their flight profile as early as possible to allow the controller to adjust the traffic flow.

TURBULENCE

Problem Area

Policies and published procedures which dictate pilot operations in turbulence appear to differ from actual practice. "Company" policy and FAA-approved ground schools advocate avoidance of various intensities of turbulence consistent with type aircraft. In practice, nearly all pilots have flown (and continue to fly) through areas of forecast turbulence of greater intensity than their aircraft are designed to withstand, a potentially dangerous practice, the results of which may be found in aviation accident reports. Reasons given for such actions vary from pilot skepticism of turbulence forecast accuracy to a desire to complete the flight as originally planned and/or a belief that a particular aircraft is strong enough to withstand the level of forecast turbulence. Until evidence if offered which provides conclusive proof existing turbulence forecasting parameters are correct, it is logical to assume pilots will continue to avoid turbulence only when it suits their needs or they are convinced of its presence.

Research Required

To provide a basis by which policy and practice may be brought together, a study of pilot and controller actions during turbulence operations should be conducted. This study might be expanded to include pilot/controller actions during all severe storm operations. The study should include behavioral factors and have as its objective the identification of:

- Specific information required by the pilot and/or controller upon which to base their decision to continue along the planned route of flight or proceed along an alternate route.
- The time frame within which this information must be made available.
- The format which will provide the information in the most concise, easily understood manner.
- What affect this information will have on pilot and controller workload and their ability to interpret and use the continual flow of weather information.

Separate from the recommended study, a review of past severe storm accidents should be made to determine if our communications systems have failed to deliver, for whatever reason, information known on the ground to the cockpit or controller. Results of the review, if it indicates communications breakdown did contribute to any of the accidents, should be used to develop interim procedural and/or equipment changes until such time as a faster, more reliable communications system becomes available. Finally, research should continue to develop a detection system similar to that described under Wind Shear which will allow weather forecasting to accurately forecast the location and intensity of turbulence.

Information Transfer Mechanism

Acknowledging the impreciseness of turbulence forecasting and detecting, the single most real time means of identifying the presence of turbulence, its locations and relative intensity, comes from the pilot. The passing of PIREPS should be stressed by management and given full support by pilots.

Aviation Safety

Until a more precise system for detecting/predicting turbulence becomes available, emphasis on the importance of remaining clear of areas of forecast turbulence if its intensity exceeds the limits of the aircraft must be stressed in the classroom and at pilot briefings. Study results and the introduction of accurate detection equipment (described under Wind Shear) may later be used to develop a policy considered realistic and which will be adhered to by all pilots.

SUMMARY REPORT: AIRPORTS COMMITTEE

William J. Hall

Tennessee Bureau of Aeronautics

Members: William J. Hall, Chairman; Tennessee Bureau of Aeronautics
Don E. Durham, Embry Riddle Aeronautical University
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Joseph M. Schwind, Air Line Pilots Association
Tom Yager, NASA Langley Research Center

Introduction

The Airports Committee was established for the first time this year, and half of our committee members had not attended either of the two previous annual sessions. As a result of these two factors, it required a good bit of deliberation by our committee to determine the airport's relationship with those other elements in a safe aviation system relative to meteorological factors. Two ideas surfaced during our discussions which set the tone for our subsequent sessions with the floating committees:

1. The distinction between weather reporting (basically air carrier) and non-weather reporting (basically general aviation) airports, and

2. The climatological variation extremes in our country which dictate the need for discretion in implementation of all recommendations.

Significant Problem Areas

1. Many airports have some form of instrument approach but no on-field weather information (wind direction and velocity, temperature, altimeter settings, ceiling heights, etc.).

2. There is a definite need for more timely and accurate wind information within critical airport areas (touchdown and approach zones). An interesting fact associated with this is Chicago's O'Hare Airport's midfield wind sock is some 2.6 miles away from the most distant runway threshold.

3. The need was recognized for more accurate weather forecasts, with a shorter interval between forecast periods. Forecasts for the lifting of fog or falling of snow are obviously very critical for airport management and operational personnel.

4. The accumulation and removal of water, ice, slush and snow from active runway areas is of paramount importance to airport operations. The more "tools" or aids available and at the disposal of those operators, the better he is able to maintain the airport in a safe operating condition.

Recommended Actions

The following recommended actions are presented in numerical order corresponding with the respective identified problem areas:

1. The expeditious implementation of automated weather observation stations and automated pilot information systems should be funded by the FAA's F & E program at selected instrumented airports.

2. A study should be conducted to determine what the most favorable types of weather sensory instruments and their respective locations should be, both on the airport proper and out on the runway approach areas.

3. There should be an increase in the numbers of weather forecasters who specialize in aviation so as to provide an adequate distribution throughout the country for timely and accurate weather forecasts.

4. The FAA should place a greater emphasis on runway grooving and should encourage the installation of in-pavement temperature and moisture sensors.

5. A final recommendation concerned the ADAP trust fund. With some 3.2 billion dollars in the fund, and with much of the needs discussed during the seminar related to required expenditures of funds, our committee recommends that trust fund money be released at an accelerated rate for safety-related improvements.

Conclusions

The workshop proved worthwhile from the participants' standpoint and hopefully will have a positive impact on those who make important final decisions in such matters.



WINDS
AND
WIND
SHEAR
COMMITTEE

SECTION VII

SUMMARY REPORTS

OF THE FLOATING COMMITTEES

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ICING
AND
FROST
COMMITTEE



ATMOSPHERIC
ELECTRICITY
AND
LIGHTNING
COMMITTEE

FOG,
VISIBILITY
AND
CEILING
COMMITTEE





TURBULENCE
COMMITTEE

SUMMARY REPORT: WINDS AND WIND SHEAR COMMITTEE

Thomas P. Incrocci

Air Weather Service/Scott Air Force Base

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Winds and wind shear are two major problems of concern primarily to different segments of the aviation community. More wind observations and more accurate wind forecasts below 10,000 feet seem to be of primary concern to the general aviation while low level wind shear is more of a concern to jet aircraft operations, and the heavier the aircraft, the greater the concern.

This committee's attempt to follow the workshop guidelines produced these topical areas of concern in aviation meteorology with respect to winds and wind shear.

- Remote Probing of the Atmosphere
- Better Forecasting Techniques
- Timely Communication of Information
- Optimum Use of Information
- Adequate Training for Meteorologists and Aviators

It is difficult to prioritize these areas. Rather there has to be an integrated effort among all the participants from these areas of interest. The researcher, the aviator, the forecaster, the modeller, the communicator have to develop a roadmap to obtain optimum solutions to a specific problem. There must be ongoing parallel efforts to bring any program to a timely and useful completion. Without direction given to the researcher, without preparations to communicate and train operators to use new or improved information, a program or project may go awry;

and if important measurements cannot be integrated into models, be used by forecasters, or be understood by aviators, the program or effort will not be successful.

The state of the art for measuring winds and wind shear is advancing, but of more importance is the application of available technology to obtain additional or specialized information.

1) Doppler radar systems, both ground-based and airborne, can observe vital wind information. The application of Doppler radar holds considerable promise for scanning up the glidescope to identify wind shear conditions.

2) The application and testing of scanning radiometer devices hold a near-term potential for providing important operational wind shear recognition. The scanning radiometer on board an aircraft shows strong potential in identifying the wind shear hazard. Future research for ground-based testing and application of the scanning radiometer requires support too.

3) Laser technology requires further investigation before it can make a positive contribution to atmospheric measurements.

We need to have improved communications and condensation of information to help aviators make decisions and controllers pass vital information. The data uplink of Doppler radar-derived information on winds, wind shear, etc., directly to an aircraft is feasible. On-board minicomputers could process the data and derive appropriate command displays. Assessing Doppler wind measurements and categorizing according to aircraft types or acceptable operating envelopes could also expedite the flow of information.

We need to support efforts in boundary layer research to improve knowledge and understanding of wind shear. Our programs on wind shear have by no means done everything.

We have the opportunity to improve the state of the art through better understanding and modelling of the wind environment through such projects as MINI SESAME in Oklahoma in May 79. The density and frequency of data hopefully may produce a better understanding of atmospheric conditions that produce some of the hazardous wind shear phenomena. Better predictive or measurement techniques should result from data analysis and model development.

We still need improvement in our forecasting skills for low level wind shear. While we have identified the large scale weather conditions conducive to shear, we still have problems detecting the mesoscale features which produce significant shear.

We have made positive progress in the area of wind shear observation and forecasting, but many problems remain to be solved.

At the same time all this research effort is going on, we have to continue good pilot education programs on our findings. We have produced a lot of information for pilots, and we must continue prompt updates as we learn more about wind shear. We need to dedicate the time and resources to the job and do it with effective training materials. For example, everyone may not experience wind shear conditions, but you can educate people to recognize the danger through the introduction of hazardous wind profiles in the flight simulator. The convincing of aircrews may take time, but there is at least one Air Force aircraft for which better flight procedures have been directed if the aircrew is to penetrate a known shear condition. The procedure allows an assessment to determine if the penetration should be attempted.

The following are problem areas, action items, or areas of further investigation which ensued from committee interactions.

1) Update siting criteria for anenometers and supplemental wind detection aids (OPR: FAA). This will help to improve wind observations with respect to aircraft operational needs by placing more instrumentation, including wind socks, near touchdown zones.

2) More representative wind observations needed for special programs, e.g., downwind takeoffs for noise abatement programs.

3) Uplink ground-based wind data to the cockpit via data link systems and display wind profiles visually.

4) Improved presentation of wind information for relay to pilots without increasing the workload on the controller.

5) Develop a catalogue on additional recorded weather data sources, especially near airfields, to assist in accident investigation (OPR: NWS/FAA). There are valuable sources of weather information, e.g., pollution control districts, available around many airports. The source may be perishable if the need for the data is not made in time. The weather information is often useful in assessing accident scenarios.

6) Add a data recorder capability to Low Level Wind Alert System (LLWAS).

7) Make a concerted effort to obtain more real time wind and temperature information from INS-equipped aircraft.

8) Obtain more wind information from general aviation pilots to update and supplement routine weather observations and communicate it to other users.

9) Make available observed winds to the general aviation community as early as possible and advertise the availability of the data through appropriate publications.

10) Update aircrew understanding and training of meteorological conditions which may create a low level wind shear (LLWS) hazard. Of particular concern is the LLWS hazard at the base of a thunderstorm downdraft. Accident analyses show this to be the worst threat area rather than the leading edge of the thunderstorm gust front.

11) Encourage continued development of Doppler radar and IR techniques for the detection of winds and wind shear and the utilization of these data.

We also wish to include in our report a summary of activities which the British Meteorological Office (BMO) has undertaken with respect to winds and wind shear. The BMO has similar interests and projects, and their findings and efforts can provide added information to help resolve general and commercial aviation problems. A detailed summary on these efforts is provided in the following appendix.

APPENDIX

UNITED KINGDOM WORK ON LOW-LEVEL WIND SHEAR AND SURFACE WIND VARIABILITY

M. J. Dutton

British Meteorological Office

1. Low-Level Wind Shear Warnings at Airfields

a) 1977 Wind Shear Warning Trials (BA/Met Office)

Analysis of the subjective pilots' reports of wind shear from the 1977 low-level wind shear warning trials at Heathrow (organized jointly by British Airways and the Meteorological Office) indicated that the warning scheme tested possessed some degree of statistically significant skill. Pilots reported wind shear on 0.4% of takeoffs/landings when a warning* was not in force, compared with about 4% of takeoffs/landings when a warning was in force. (Note the high false alarm rate--when a warning was in force 96% of aircraft movements were apparently unaffected by wind shear.) However, subjective/psychological factors cloud the issue here, and in order to obtain a more objective measure of the skill of the warning scheme, analysis of the information on head wind variations derivable from digital flight recorder data (from British Airways aircraft) covering the period of the Heathrow 1977 Trials is now in progress. Flight data from about 400 takeoffs/landings are usable. A wind shear analysis program based on software developed at RAE Bedford is being applied to the data to extract quantitative wind shear information from each flight.

b) Operational Wind Shear Warning Service (Met Office)

The inauguration of an operational wind shear warning service (similar to the one tested in the 1977 trials) at Heathrow and one or two other large civil aerodromes is planned for summer/autumn 1979.

2. Examination of Past Data on Wind Shear Events

a) Civil Aviation Airworthiness Data Recording Program (CAADRP) Panel

This is a panel of experts (with representation from Civil Air Authority [CAA], Royal Aircraft Establishment [RAE], Meteorological Office, British Airways [BA], British Caledonian Air Lines [BCAL], Gulf Air, and British Air Line Pilots Association [BALPA]) who regularly examine abnormal events, whatever the cause, detected during scanning of aircraft flight data recorders from a small sample of

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*Decision whether or not to issue warning made hourly.

large civil jet transport aircraft. These abnormal events are the output of a computer-programmed sifting process designed to highlight occasions when the aircraft-recorded variables fall outside prescribed limits. A small proportion of these events turn out to be attributable, in whole or in part, to wind shear.

b) Routine Analysis of Aircraft Data for Wind Shear (BA/RAE/Met Office)

Proposals by RAE, Bedford, for a scheme for routine analysis of aircraft (British Airways) flight records, specifically for wind shear content, are being considered by British Airways (BA). RAE have suggested that their own software, which they have developed specifically for application to series of aircraft-experienced head wind components, could be readily applied to BA's flight cassettes with relatively little effort or cost, yielding wind shear statistics from several thousand flights per year. (Initially effort would be concentrated on records from INS-equipped aircraft only--mainly B-747's--and on the lowest 600 meters of the approach to landings.) One important aspect of the project would be that while the large majority of flight data would involve no more than computation and counting of wind shears (so-called "ramps" and "ramp pairs") classified by time interval, intensity, height and airfield; data relevant to extreme events would be printed out (digitally and graphically) for careful scrutiny. The Meteorological Office may become involved in examination of the meteorological circumstances of these extreme events.

c) Squall-Type Events at Heathrow (Met Office)

A manual analysis of anemograph traces for large rapid surface wind changes recorded at the Heathrow southwest site anemometer during 1977 showed that about 90% of such events were associated with the occurrence of cumulonimbus clouds, the passage of a front (normally a cold front) or showery precipitation. Work is still in progress and a computer program is being developed to objectively scan continuous series of 30-second wind data for this type of event which obviously constitutes a potential hazard to aircraft on the approach and climb-out. The main application of the results of this study will be in the field of flight simulator studies; data on actual squall-type events could be used to construct realistic wind series for input to simulator studies of wind shear (see Section 4).

d) Simultaneous Wind Data from Heathrow Anemometer Sites (Met Office)

Two Digital Anemograph Logging Equipment (DALE) units have recently been installed at Heathrow to record continuously (over a period of about a year) 30-second averages of surface wind at the two anemometer sites, in the southwest corner near the threshold of 10R and in the northeast corner near the threshold of 28R. CAA

had previously expressed an interest in acquiring reliable statistics of simultaneous two-point wind differences between these two sites, and the DALE data are intended to satisfy that requirement. CAA are particularly interested in the occurrence frequency of large horizontal shears of wind across the aerodrome.

3. Remote Detection of Wind Shear

a) Laser System (RAE)

A ground-based laser anemometer (measuring line-of-sight wind component) currently under trial at RAE Bedford has attained a maximum range of about one kilometer. The group at Bedford plan to enhance the range capability of the system by the use of increased mirror apertures. Their plans also include the development of a compact airborne version of this equipment which will detect variations in line-of-sight wind component on the projected flight path of the aircraft, a few hundred meters ahead of it, the information being passed directly to the aircraft's guidance and control system which would be programmed to apply the control inputs most likely to maintain a stablized flight path; an airborne laser anemometer is expected to be ready for in-flight trials (in a HS-125 aircraft) during 1979.

b) Pulsed Doppler Radar System (Met Office RRL)

The Meteorological Office Radar Research Laboratory (RRL) at Malvern is currently involved in developing a microwave pulsed Doppler radar (PDR) with a line-of-sight wind measurement facility similar to a laser system, but with much increased range capability (up to about 10 km); a PDR system is also claimed to be less weather-sensitive than laser devices. Following development of a viable system, trials of its potential as an operational (ground-based) tool in wind shear warning schemes at airfields will go ahead.

4. Flight Simulator Studies (CAA, RAE, BA, other airlines)

Flight simulator studies of wind shear and the operating techniques necessary to counter it have been going on at RAE Bedford. These studies include examination of the requirements for new instrumentation. Pilots from civil airlines, RAE and CAA have been exposed to various wind shear conditions while flying approaches through varied visual sequences. The aircraft simulated are of the BAC 1-11/Trident type. The objectives of these studies are:

a) To generate realistic simulation of the wind structures typical of those found in the meteorological situations likely to produce severe wind shear incidents.

b) To establish the validity and limitations of current handling techniques and procedures.

c) To assess the need for additional or modified handling procedures or instrumentation to help counter the effects of wind shear.

d) To evaluate any procedures or instrumentation indicated by (c).

e) Ultimately, using the Filton simulator purely as a computer without pilot involvement, to make an attempt to assess the capability to utilize advance information on the state of the atmosphere such as might become available from an airborne remote-sensing laser anemometer.

5. Miscellaneous activity.

a) Steering Group on the Acquisition and Operational Use of Boundary Layer Measurements (Met Office)

This is a Meteorological Office group with the following terms of reference:

- To keep under review the requirements for observations within the boundary layer for operational purposes, as well as potential methods for satisfying such requirements.

- To make recommendations concerning the conduct of trials to determine the feasibility of observational techniques and the utility of observations so acquired.

- To consider the results of any trials and to make proposals concerning the operational introduction of instruments and methods.

This group is currently coordinating a trial of routine dissemination to forecast offices of Lichfield ITA tower (near Birmingham) observations for use in operational forecasting. The wind sensors at 23m, 117m and 247m are currently inoperative and will be replaced during April. The requirement for further Met Office instrumentation of tall towers will depend on the results of the Lichfield trial. It is also expected that with the cooperation of the Central Electricity Generating Board (CEGB), observations of wind (at 200m and 300m), temperature and humidity from the Belmont tower in Lincolnshire can be made available in near-real time to local forecast offices later this year.

b) Surface Wind Information Study Group (CAA/Met Office)

This group, which recently held its first meeting, has the following terms of reference:

- To identify precisely the surface wind information required by aircraft on the approach to land and immediately before takeoff.

- To examine the present means of assessing and passing wind information to aircraft.

- To study recent research and development of new equipment for improving the accuracy of surface wind information and to relate this to the identified requirements of aircraft.

- To make recommendations with a view to improving the accuracy and transmission of surface wind information to aircraft to help minimize the hazards of crosswind and wind shear.

- To present the results for consideration by the wind shear committee of the CAA.

Among other things, the case for introduction of standardized digital displays of wind information (including the International Civil Aviation Organization-recommended [ICAO] two-minute average and maximum gust during the previous ten minutes) will be assessed. Past studies within the Met Office (see for instance Dutton [1975, 1976]) lend support to ICAO-recommended two-minute averaging period for reports of surface wind to pilots shortly before takeoff and touchdown.

c) Study Group to Consider Runway Selection Procedure in Light Winds

The CAA are considering the formation of a further study group to consider runway selection procedures at large airfields in conditions when the surface wind is light. In particular, consideration will be given to the advisability of taking into account the direction and strength of the upper flow over the airfield (as estimated, for instance, by the gradient wind) in any choice of runway direction in light surface wind conditions.

REFERENCES

Dutton, M. J. O., Optimum averaging time of wind reports for aviation, Met. Mag., Vol. 104, pp. 231-243, 1975.

Dutton, M. J. O., Optimum averaging time of reports of along-runway and across-runway wind components to aviation, Met. Mag. Vol. 105, pp. 343-350, 1976.

SUMMARY REPORT: ICING AND FROST COMMITTEE

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In this summary report, the Icing and Frost Committee has delineated the major topic areas of the various interaction meetings with the fixed committees. Icing and frost problems are identified as they pertained to each group represented by the committees on: training, flight operation, air traffic control, accident investigation, and airport operation. An attempt has been made to establish the type of research and training programs that would assist in alleviating and solving the problems. The problem areas identified in this report are not an exhaustive list of ice- and frost-induced problems, but merely reflect the topic areas of our interaction meetings with emphasis on the types of icing problems that pertain to the members of the fixed committees.

During the past year, two other workshops have dealt with the aircraft icing problem. In March 1978, the Second Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems considered the icing problems with emphasis on helicopter icing. A July 1978 conference on icing held at NASA Lewis Research Center in Cleveland, Ohio, also reviewed in detail aircraft icing with special consideration of the helicopter icing programs initiated by the U.S. Army and the FAA. References 1 and 2 give a well documented description of the present state of the art of helicopter icing research. Consequently, the Icing and Frost Committee discussions largely focused upon icing and frost problems as they relate to fixed-wing aircraft.

The Icing and Frost Committee Summary is divided into four sections: icing and frost problems as they pertain to general aviation aircraft; icing and frost problems as they pertain to air carrier aircraft; icing and frost forecasts; and icing terminology and symbology. In each section, a description of the problem is given and those aviation groups which it affects, as represented by the fixed committees, are delineated. Given next are possible approaches toward solving the

problem, and finally areas are defined where further research and training programs are recommended.

ICING AND FROST EFFECTS ON GENERAL AVIATION AIRCRAFT

Airframe Icing

Problem: Wing and airframe icing remains a serious safety hazard for general aviation aircraft not equipped with anti-icing equipment. Discussions with the various fixed committees indicated an influence of airframe icing on aircraft operations, training, accident investigation, and air traffic control.

Approaches Toward Solution: An inexpensive, yet effective, ice protection system is needed for general aviation aircraft. Though such a solution may not be imminent at the present time, research and training programs that lead toward partial solutions should be pursued.

Research and Training Needs:

- Continue research into the potential use of ice-phobic coatings on airfoils to prevent large and rapid accumulations of ice.
- Continue development of inexpensive ice detection and cloud parameter instrumentation for general aviation.
- Perform research to define the sensitivity of each aircraft design to ice accretion.
- Pursue study of the aerodynamics of those shapes that are found to be less sensitive to ice accretion.
- Establish a method of reporting all general aviation icing encounters to air traffic control in a reliable and timely fashion. Presently the air traffic controller tends to receive only those icing reports from aircraft who are experiencing significant difficulties.
- Determine a proper program of pilot instructions concerning problems associated with ice accretion. The Training Committee expressed an opinion that they do not know precisely what instructions a pilot should receive concerning the various aspects of icing. Thus, it is recommended that the present training program be reviewed and analyzed with respect to factors such as:
  - the recognition of conditions conducive to ice formation;
  - the effects of ice accretion on aircraft performance;
  - the possible use of simulators programmed with aerodynamic penalties representing ice accretion; and
  - the related secondary problems such as increased fuel consumption.

Frost on the Airfoil

Problem: The overnight accumulation of frost on an airfoil can produce significant aerodynamic penalties during takeoff. Accident investigations have determined frost on the airfoil to be a contributing factor to many general aviation accidents. Discussion with the various fixed committees determined the frost problem to have an influence on aircraft operations, training, accident investigation, and to some extent, airport operations.

Approaches Toward Solution: An inexpensive frost removal technique for general aviation aircraft would largely solve the problem. A deicing aerosol, for example, to rapidly melt frost without danger of refreezing would be most desirable. A partial solution might be directed toward a training program for recognition of frost-induced aerodynamic penalties and optimum takeoff procedures.

Research and Training Needs:

- Establish the severity of the frost problem for various airfoil configurations by means of an accurate quantization of frost-induced aerodynamic penalties versus frost thickness and density. An ongoing NASA-funded research program is addressing this problem.

- Since the frost problem is regional within the United States, review training programs to assure that pilots from frost-free areas are adequately prepared to deal with the problem when flying in colder regions of the country.

- Develop an inexpensive and effective frost removal process for general aviation aircraft.

Carburetor Ice

Problem: On general aviation aircraft equipped with Venturi type carburetors, ice accumulation on the throttle plate and in the throat of the carburetor can produce loss of engine power and even engine failure. The carburetor icing problem affects those personnel involved in aircraft operations, training, and accident investigation. In accident investigation, engine failure due to carburetor ice is an extremely difficult factor to establish.

Approaches Toward Solution: The best solution to the carburetor ice problem is to prevent its formation. Approaches include anti-icing fuel additives and throttle plate coatings that prevent ice adhesion. Partial solution approaches would include an accurate, reliable and inexpensive ice detector and intense training towards recognition of carburetor ice accretion.

Research and Training Needs:

- Evaluate present carburetor ice detectors and pursue development of a reliable, accurate and inexpensive ice detector if necessary.

- Review training programs relating to carburetor ice detection with respect to the meteorological conditions under which it is most likely to occur, the symptoms to recognize carburetor ice, and the proper procedures for applying corrective measures.

ICING PROBLEMS AS THEY PERTAIN TO AIR CARRIER AIRCRAFT

Engine/Ice Ingestion

Problem: During takeoff ingestion of ice or slush on a semi-frozen runway can cause engine flameout or structural damage to an engine. This problem has an impact on both aircraft operations and aircraft training.

Approaches Toward Solution: Proper training procedures should be established to assure recognition of the hazard and appropriate action.

Research and Training Needs:

- Review present training programs to establish whether the problem is receiving adequate attention and whether the best techniques and procedures are being taught.

Tail Icing While in a Holding Pattern

Problem: Many of the air carrier fleet have no anti-icing equipment for the tail of the aircraft. When in a holding pattern, significant ice buildups can occur on the tail which degrade the performance of the aircraft. Present aircraft in certification have not experienced the length and severity of icing conditions that can occur in a holding pattern. The problem has an impact upon the air traffic control and operations segments of the aviation groups.

Approaches Toward Solution: The possibility of change in certification for future aircraft should be considered. Air traffic control should be trained in special handling procedures.

Research and Training Needs:

- Train ATC personnel to recognize the special handling that is required for aircraft not equipped with anti-icing equipment to maintain holding patterns in severe icing conditions.

- Arrange for ATC to train those affected to recognize the problems of the longer distance required to reduce speed when an aircraft is using its anti-icing equipment.

- Review Federal Air Regulations concerning tail icing for extended lengths of time.

Runway Ice and Snow

Problem: The rapid and efficient removal of ice from runways presents a serious challenge for airport operations. Monitoring of the runway condition is an equally important problem that affects both airport and aircraft operations.

Approaches Toward Solution: Partial solutions to the problem should be addressed toward better techniques for snow and ice removal, for measuring the coefficient of friction of the runway surface, and for improved monitoring and reporting techniques for the surface conditions of the entire runway.

Research and Training Needs:

- Continue research into improved snow removal techniques. Programs by the Canadian National Research Council are considering airblast techniques and microwave techniques for runway snow removal.

- Conduct research to more accurately measure the coefficient of friction on slippery runways. A promising new instrument developed in Sweden by SAAB should be fully evaluated for its ability to accurately measure the coefficient of friction.

- Conduct research to establish a more accurate and reliable technique for the continuous monitoring of slush and snow depth on the entire runway.

- Conduct research to establish the actual acceleration degradation experienced by an aircraft during takeoff under varying amounts of slush. Although aircraft are certified for takeoff in a specified amount of slush, the actual safe takeoff capability of most aircraft has not been established.

Frost on the Airfoil

Problem: Air carriers are not permitted to take off with a frost coating on the airfoil. Thus, an economic penalty exists due to the removal of frost prior to takeoff. The actual performance degradation due to frost on the airfoil of a large fixed-wing aircraft remains a largely unknown parameter.

Approaches Toward Solution: Those frost conditions which produce serious performance penalties should be established. The possibility of takeoff under modified takeoff constraints should be determined.

Research and Training Needs:

- Establish the drag and lift penalties associated with various types of frost on an airfoil versus its thickness and density. An ongoing NASA-sponsored research program is addressing this problem.

- Determine if takeoff with an adequate safety margin is possible for an aircraft with a frost-coated airfoil by reducing gross weight, by lengthening the runway, or by using a modified takeoff procedure.

ICING AND FROST FORECAST FOR AVIATION

Icing Forecast

Problem: Icing forecasts, both terminal and en route, affect all segments of aviation that were represented by the fixed committees. The accuracy of these forecasts is known to be deficient and is an area where major improvement is possible and substantial benefits would be reaped. Because this topic has been adequately reviewed in previous icing conferences [1,2], the committee spent little time discussing the ice and frost forecasting problem. The committee does recommend that a continued and expanded effort be addressed towards improving all phases of icing forecasts.

ICING AND FROST TERMINOLOGY AND SYMBOLOGY

Icing Terminology

Problem: Terms used in describing icing conditions, such as trace, light, moderate and severe, are ill-defined and require subjective interpretation on the part of both the observer and the user. Similarly, the distinction between wet and dry snow on a runway surface is a subjective decision. The problem affects those committee groups concerned with air traffic control, training, accident investigation, and airport and flight operations.

Approaches Toward Solution: An objective standardized set of terminology for icing parameters is needed. The committee recommends that this standardization be an integral part of a larger standardization program for terminology and symbology dealing with all facets of aviation meteorology.

Research and Training Needs:

- Develop appropriate instruments to define icing severity levels to include measurement of liquid water content (LWC), outside air temperature (OAT), and perhaps median droplet diameter (d). The severity level classification should range over those combinations of these parameters that produce extremely light to the most severe icing conditions for any aircraft.

- Establish a research program to rate each aircraft type according to the severity level classifications. Benchmark values should be established relating LWC, OAT, and d values to ice accretion rates for each aircraft type.

RECOMMENDATION

The Icing and Frost Committee recommends that the above problem areas and research training needs be reviewed by the appropriate NASA, FAA, NOAA, and DOD research program offices relative to their existing ice and frost research programs. Where deficiencies are found, the severity of the icing problem should be weighed relative to its impact on aviation safety and acted upon accordingly. The following appendix outlines the present icing research program of NASA. Information on research programs initiated by other agencies can be found in References 1 and 2.

REFERENCES

1. Frost, W., and D. W. Camp, eds., "Proceedings: Second Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems," The University of Tennessee Space Institute, Tullahoma, Tennessee, NASA-CP-2057, FAA-RD-78-99, March 1978.

2. "Aircraft Icing"--A Workshop held at NASA Lewis Research Center, Cleveland, Ohio, NASA-CP-2086, FAA-RD-78-109, July 1978.

APPENDIX

AIRCRAFT ICING RESEARCH AND TECHNOLOGY PROGRAM AT NASA

There is an increased need and desire for aircraft to be able to operate safely in atmospheric icing conditions. This need exists in the following aircraft types:

- Civil Helicopters--search and rescue, and support of off-shore oil rigs.
- Military Helicopters--tank defense in Europe.
- General Aviation--most single engine propeller aircraft are grounded when icing conditions are forecasted.
- Commercial Aviation--especially the small commuter airlines operating in the snow areas.
- Military Aircraft--especially strategic aircraft that fly for long periods at low altitudes to avoid radar detection.
- Cruise Missiles.

The highly successful workshop on aircraft icing problems held in July, 1978, at the Lewis Research Center is evidence of the worldwide interest in this problem. The workshop was attended by 100 icing experts including representatives from Canada, England, France, The Netherlands, Sweden and West Germany. The increased interest in this country is shown by a full schedule of tests by industry in the Lewis Icing Research Wind Tunnel (IRT) during CY 1978 and 1979. These tests include:

- Deicing systems for helicopter blades and engine inlets
- Missile launchers
- Pneumatic deicing boots for wings and rotor blades
- Ice detection instruments
- Ice phobics
- Spray bar system for the Army HISS tanker
- Advanced aircraft ice protection systems

The IRT has a 6 x 9-foot test section and is the largest icing wind tunnel in North America.

NASA Lewis' response to this increased interest has been the creation of a new Icing Research Section in the Low Speed Aerodynamics Branch

of the Wind Tunnel and Flight Division. The purpose of this section is to establish the research and technology base to design and develop aircraft ice protection systems and icing instrumentation that will allow both rotorcraft and fixed-wing aircraft to operate safely and efficiently in atmospheric icing conditions.

The Icing Research Section will:

- Perform the following kinds of experiments in the IRT.
  - Fundamental icing research experiments
  - Aircraft component icing
  - Icing instrumentation research
  - Cloud instrumentation research
  - Advanced ice protection systems research
  - Aircraft tanker spray systems
- Develop computer codes for water droplet trajectories for external and internal flows.
- Investigate fundamentals of the ice accretion process.
  - Heat transfer
  - Thermodynamics
  - Aerodynamics
- Develop computer models for the prediction of ice accretion.
  - Employ theory and numerical analysis.
  - Verify models with experiments in the IRT.
- Investigate the fundamental mechanisms of:
  - Ice adhesion
  - Ice fracture
  - Ice shedding
- Investigate shed ice trajectories.
- Investigate scaling laws for scale model testing in icing wind tunnels.
- Conceive, develop and test advanced ice protection systems.
  - More effective than some present systems
  - Have low cost, weight and power consumption
- Determine new ice protection requirements for future aircraft.
  - New aircraft designs
  - New missions
  - New materials (composites, etc.)

This work will be done in-house and through industrial contracts and university grants.

FY 1979 and 1980 programs include the following tasks:

- Water droplet trajectory computer programs (including graphics package) for internal and external potential flows
- Non-intrusive laser interferrometer system to measure water cloud parameters in the IRT
- G.A. icing requirements study by industry
- CTOL icing requirements study by industry
- Rotorcraft icing requirements study by industry
- Microwave airfoil deicer development program
- NASA-BF Goodrich helicopter deicer boot tests
- USAF ice phobics tests
- US Army HISS spray bar tests
- Ice interface shear measurements
- Survey of aircraft icing test facilities in North America
- Aerodynamics of water-separating engine inlets
- Effects of ice on engine inlet aerodynamics
- Recalibrate and expand capabilities of the IRT
- Experimental appraisal of known ice scaling relations

Longer range goals include the following:

- Develop a series of ice protection design computer codes.
  - Water droplet trajectories for internal and external flows
  - Anti-icing heat transfer
  - Ice accreted shapes
  - Internal heat transfer
  - Shed ice size and trajectories
  - Associated graphics
  - Minimum ice sensitivity airfoil shapes
  - Minimum water catch airfoil shapes
- Install a rotating rig helicopter test pad in the IRT

- Develop ice accretion, heat transfer, aerodynamic and shed ice trajectory scaling relations for scale model testing.

- Stimulate further research on new concepts for aircraft ice protection systems and icing instruments.

  - Microwave: deicers; ice detection and thickness instruments
  - Piezoelectrics: coatings; polymers; composite materials
  - Magnetics: impulse coils; composite materials
  - Mission adaptive airfoils used for deicing
  - Hydraulic and mechanical surface deformers

- Reexamine pneumatic boot design procedures by applying modern structural anlayses to ice adhesion and ice fracture processes.

- Develop engine inlet design procedures for deicing, anti-icing and water separation.

SUMMARY REPORT: ATMOSPHERIC ELECTRICITY AND LIGHTNING COMMITTEE

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The committee reviewed the lightning-related activities of the past year versus the recommendations made by the committee during the 1978 workshop[1] and recognized only modest accomplishment since that time. The in-flight measurement activities of NASA and the Wright Patterson Air Force Base were recognized. The proposed military specification for Lightning Qualification Test Techniques for Aerospace Vehicles and Hardware generated by the Society of Automotive Engineers Committee SAE-AE4L for implementation by USAF AFSC was noted; the need for a user's manual for the specification and an induced effects test specification were discussed.

The committee recommended increased emphasis on research relating lightning to the meteorological environment. An updated prioritized list of lightning protection technology needs is appended; Item 5 in the Appendix reflects the above research.

The following summarizes the discussions between the Atmospheric Electricity and Lightning Committee and the various fixed committees.

Flight Operations

There was considerable discussion centered on the need for a meteorological hazard detection/warning system which could include lightning as one of the parameters. The need was recognized for both a ground-based system and an airborne system; the airborne system performance could be relaxed (compared to the ground-based system) due to technological problems associated with accurate lightning detection from a single station. A need was discussed for a comprehensive lightning strike reporting system to aid in identifying the effects of lightning on present systems, particularly regarding

general aviation aircraft; also noted was the requirement for commercial sector strike reporting.

Training

A good portion of the discussion concerned review of the phenomena of precipitation static. An outgrowth of that discussion, itself, was recognition of need for education concerning the lightning/precipitation static environment and its effect on systems. The committee consensus was that a useful monograph could be generated but the committee was not able to identify an appropriate mechanism for dissemination of such information.

Air Traffic Control

Air traffic control problems related to lightning were discussed; lightning phenomena and the vulnerability of ground-based systems were reviewed. The potential utility of a lightning-augmented meteorological hazard warning system was discussed. The consensus was that such a system would be useful but that implementation and introduction would be a long-term effort.

Accident Investigation

A need was identified for a recording system for lightning strike evidence for use in accident investigations. A need exists both for present technology aircraft and for advanced aircraft employing fly-by-wire control systems. The concern was that fly-by-wire systems may be upset by lightning (with no lasting physical evidence of the lightning event). The position of industry members on the committee was that such a system could be developed upon generation of a formal requirement.

Additionally, a need was identified for the training of accident investigators on the effects of lightning on aircraft.

REFERENCES

1. Frost, W., and D. W. Camp, eds., "Proceedings: Second Annual Workshop on Meteorological and Environmental Inputs to Aviations Systems," The University of Tennessee Space Institute, Tullahoma, Tennessee, NASA-CP-2057, FAA-RD-78-99, pp. 211-214, March 1978.

APPENDIX

LIGHTNING PROTECTION TECHNOLOGY NEEDS IN ORDER OF PRIORITY

	NEED	NATURE OF PROBLEM	TIME REQUIRED	IMPACT OF PROBLEM	COST BENEFIT	EFFORT REQUIRED	PARTICIPANTS
1.	In-flight data on lightning electrical parameters: a. direct strikes b. nearby strikes c. static electricity	Lack of data.	2-4 years	Uncertain test and design parameters.	Increased flight safety, especially under IFR conditions, quicker and more confident introduction of new technologies.	New effort	Major role: Government, supporting role: contractors.
2.	Technology base and design guidelines for protection of advanced aircraft systems and structures.	Lack of design data, R&D.	2-6 years	Increased safety hazards; decreased use of advanced technology.	See above.	Some knowledge in-hand, but major new effort is required.	Government/contractors: improved data base airframe manufacturers: specific applications.
3.	Improved test techniques for: a. induced effects b. blast effects.	R&D	2 years	Increased hazards; decreased use of advanced technology.	See above.	Continued effort.	Government and industry.
4.	Analysis techniques for predicting induced effects.	R&D	3 years	More Cut-and-try.	See above.	Some new effort.	Government and industry.

APPENDIX
(cont'd)

NEED	NATURE OF PROBLEM	TIME REQUIRED	IMPACT OF PROBLEM	COST BENEFIT	EFFORT REQUIRED	PARTICIPANTS
5. Fundamental research on the Lightning environment and its relationship to other meso-scale parameters associated with thunderstorms such as temperature, wind velocities, hydrometeors, etc. associated with thunderstorms.	Lack of data and correlation.	5-20 years	Relative lack of understanding of the lightning interaction with aerospace vehicles. Advanced warning of lightning hazard not yet available.	Prediction of the lightning phenomena for avoidance of the hazard. An increased understanding of the lightning environment will enable better model developments yielding insights concerning structural interaction with the lightning channel.	Major effort required. Merging of various technologies also needed.	Government/Airframer Manufacturer/Scientific Community.
6. More lightning strike incident data from general aviation.	Operational.	1 year.	Decresased reliability.	Increased flight safety, especially under IFR conditions; quicker and more confident introduction of new technologies.	Additional reporting effort.	General aviation industry.
7. Lightning detection systems a. air b. ground	R&D	2 years.	Continued hazard to air/ground personnel and operations.	See above.	Some new effort.	Government and industry.
8. Obtain pilot reports of lightning strikes to aircraft.	Operational and procedural.	3 years.	Increased strikes.	See above.	In hand, education needed.	Operators.

APPENDIX
(cont'd)

	NEED	NATURE OF PROBLEM	TIME REQUIRED	IMPACT OF PROBLEM	COST BENEFIT	EFFORT REQUIRED	PARTICIPANTS
9.	Better training in lightning awareness for pilots of all aircraft.	Operational and procedural.			Increased flight safety, especially under IFR conditions; quicker and more confident introduction of new technologies.	New.	All.

SUMMARY REPORT: FOG, VISIBILITY AND CEILINGS COMMITTEE

Douglas W. Downen

National Weather Service

Members: Douglas W. Downen, Chairman; National Weather Service
Neal M. Barr, Boeing Commercial Airplane Company
James T. Bradley, National Weather Service
Larry S. Christensen, FWG Associates, Inc.
Walter V. Collins, Los Angeles Department of Airports
Roger G. Flynn, Ocean Data Systems, Inc.
Ronald H. Kohl, The University of Tennessee Space Institute
Otha H. Vaughan, NASA Marshall Space Flight Center

The committee meetings covered a wide range of subjects dealing with the impacts of fog, visibility and ceilings on the aviation community. In the meetings with the fixed committees, problems, improvements required and possible solutions in the forecasting and observing of these meteorological parameters were discussed. The committee found seven areas of concern; these are presented below:

1. Aviation Forecast Timeliness

Our committee was consistently confronted with the problem of the deterioration of NWS aviation forecasts over the past ten years. Concern was voiced that the forecasts are too broad and more precise information is needed, especially the beginning and ending times of meteorological events significant to aircraft operation. There was a need expressed for more timely amendments once the forecasts are no longer valid. No statistics regarding this subject were presented, only subjective comments. If these deficiencies do in fact exist, they must be documented and presented to NWS.

2. Automated Low-Cost Weather Observation System (ALWOS)

The need for some type of automated observation at the more than 1,000 general aviation airports was discussed in all our meetings with the fixed committees. These airports have instrument approaches but no weather observations. The FAA has a development program currently underway for a system to satisfy this need. The actual development is being done by NWS's Equipment Development Laboratory. The ALWOS basic design and output were examined during our meetings and all the fixed committees were satisfied with the development to date. The

Accident Investigation Committee expressed the requirement for some type of 24-hour readily retrievable recording capability in the ALWOS. These data would be valuable for accident investigations. The ALWOS will be demonstrated in early 1980 at the Frederick Municipal Airport, Frederick, Maryland. Details on the ALWOS development and the system capability can be obtained from FAA's Aviation Weather Systems Branch, Systems Research and Development Service. A subset of ALWOS is currently being demonstrated at Frederick, Maryland. This system is called WAVE (Wind, Altimeter and Voice Equipment). The WAVE outputs each minute wind (direction, speed and gusts), altimeter and favored runway. The message is transmitted on the Frederick VOR. Each observation is prefaced by the time of the observation.

The National Weather Service has for many years been developing techniques for automating cloud and visibility observations. NWS's Test and Evaluation Division has done the primary development in this area. Results from this development will be used in the ALWOS. Two references are given at the end of the committee's report on results obtained to date.

3. Fog Dispersal

Our committee discussed the subject of fog dispersion in great detail. Techniques that have been tried and the system currently in use at two airports were covered. The committee recommends that following completion of the literature search underway by NASA on fog dispersion, the two most promising techniques be field tested.

4. VFR Adequacy

The current VFR rules may not be adequate in light of the high performance aircraft in use today. It was the committee's finding that these rules may endanger aviation safety in highly congested areas plagued by pollution. It was the committee's recommendation that the VFR rules be examined and revised if they are no longer adequate.

5. Slant Visual Range

The problems of measuring slant visual range were discussed. Many technical problems must be solved before a slant visual range sensor can be developed. The committee recommends that continued research in this area be encouraged.

6. Training

The need was expressed for short, nontechnical articles on weather. These articles are needed to keep general aviation pilots up to date. One particular area where this effort will be required is in automation. With the advent of automated observations, the aviation community must be informed on exactly what these automated systems are transmitting.

7. Standardization of Weather Data

There is a need to standardize the reporting of weather data. Without standardization, there could be misinterpretation and aviation safety would be endangered.

REFERENCES

Bradley, Lefkowitz and Lewis, "Automating Prevailing Visibility," Conference on Weather Forecasting and Analysis and Aviation Meteorology, American Meteorological Society, Silver Spring, Maryland, October 16-19, 1978.

Bradley, Lefkowitz and Lewis, "Automating Cloud Observations," Conference on Atmospheric Environment of Aerospace Systems and Applied Meteorology, American Meteorological Society, New York, New York, November 14-16, 1978.

SUMMARY REPORT: TURBULENCE COMMITTEE

R. Craig Goff

FAA National Aviation Facilities Experimental Center

Members: R. Craig Goff, Chairman; FAA/NAFEC
James W. Bilbro, NASA Marshall Space Flight Center
James E. Dieudonne, NASA Langley Research Center
John C. Houbolt, NASA Langley Research Center
John Keller, University of Dayton
Peter M. Kuhn, NOAA Atmospheric Physics and Chemistry Labs
W. Steve Lewellan; ARAP, Inc.
William T. Pennell, Battelle Pacific Northwest Labs
John Prodan, South Dakota School of Mines and Technology
Richard H. Rhyne, NASA Langley Research Center

Background of Committee Members

Composition of the Turbulence Committee was primarily research oriented as opposed to the operational orientation of the fixed committees. Research expertise covered a wide range of interests: measurements (Prodan, Pennell, Kuhn, Houbolt and Goff); instrumentation (Prodan, Pennell, Kuhn, Bilbro and Goff); dynamics (Pennell and Rhyne); forecasting (Keller); simulation (Dieudonne); and modeling (Lewellan). The makeup of the committee was, therefore, well suited to respond to the wide range of questions, comments, and demands of the operations professionals on the fixed committees.

Nature of the Meteorological Problem

Turbulence is the small-scale fluctuation of the wind due either to the effects of mechanical (shearing) forces or bouyant (convective) forces or both acting simultaneously. In the meteorological sense of the word, this covers wind fluctuations having wavelengths from roughly 3,000 m down to very small oscillations of 1 m wavelength. Oscillations of wavelength smaller than 1 m have very small amplitude and are inconsequential.

Commercial jet aircraft flying en route will respond to 100 m or larger waves, and while flying slower in the terminal area will respond to 50 m or larger waves. On the opposite end of the scale, what appears to the meteorologist as a mesoscale (middle scale) fluctuation

will be perceived by the pilot in his moving coordinate system as turbulence. Hence, there is some overlap of the meteorological and aircraft definitions of turbulence but not a precise one-to-one correspondence. This has caused some confusion in the past.

Another source of confusion for the user has been the interchange or misuse of three critical terms expressing changes in the wind: turbulence, wind shear, and up/downdraft. In the pure sense, turbulence produces rapid aircraft oscillations (shaking or small-scale pitching and yawing), wind shear is a wind discontinuity producing a change in airspeed (increase or decrease) while up/downdrafts cause a gain or loss of altitutde. However, all three can and frequently do occur simultaneously. Although turbuelnce is easy to separate from the other types of wind changes, wind shear and vertical motions are sometimes difficult to isolate because a loss of airspeed, say due to a loss of headwind in a wind shear situation, also results in a loss of altitude and may, therefore, be construed as a downdraft. This has not been fully recognized by some pilots and meteorological investigators. With this brief, possibly irrelevant comment, we return and confine our attention to turbulence.

Turbulence can occur anywhere in the atmosphere aircraft traverse. In general, turbulence frequently occurs in four locations: (1) in the planetary boundary layer (lowest 1,000 m of the atmosphere) on days when there are either high winds, ample surface heating or both; (2) in layers of the atmosphere attended by a significant wind maximum (jet); (3) in and/or near thunderstorms or developing thunderstorms (including hurricanes, of course, which are composed of thunderstorm bands); and (4) in regions where high-speed flow moves over high-relief terrain.

Although turbulence is characteristically intermittent (here now, gone a short time later), daytime boundary layer turbulence (type 1) is much less so. This is because the mechanical and/or bouyant production mechanisms are present on a more or less continuum. This makes daytime boundary layer turbulence and its average intensity highly predictable from routinely collected surface and near-surface wind and temperature observations, even from an intuitive understanding of the governing factors.

Turbulence is associated with many elements of the thunderstorm: the precipitating storm center, the cloud-free subsidence area outside, the low-level thunderstorm outflow, and the "overshooting" storm top. The intermittency which relates directly to predictability is an important consideration. Studies by Lee at the National Severe Storms Lab have shown that turbulence is not highly correlated with radar reflectivity magnitude nor the reflectivity gradient. Turbulence is not always present in the remaining three features of the thunderstorm either. Thus, we have not only the problem of intermittency, but the question of whether the turbulence occurs at all. One fact is clearly evident: turbulence, if present within a mature severe thunderstorm, is the most intense turbulence found in nature and is the most hazardous to aircraft.

Turbulence associated with wind jets (type 3) is highly intermittent and defies spatial and temporal forecastability. Jets are regions of high-vertical shear often accompanied by a temperature inversion. The shear action causes undulations in the inversion layer which may grow in amplitude to instability. These are called shear-gravity waves. Extremely unstable waves will break causing a cascade of energy to smaller (turbulence) scales. But this process is short-lived, and when the turbulent energy is nearly dissipated, the process will cease until the undulations grow and break again. The process is very patchy. It is possibly the major cause of turbulence false alarms for pilots.

Mountain wave turbulence (type 4) would appear to be predictable once the background wind is known. It is predictable, but only in the gross sense by specifying its possible incidence over part of a large area. Therefore, like jet turbulence, it is very patchy. Waves induced in the atmosphere by mountains or mountain ranges may grow in amplitude to a limit of instability whence they break into turbulent fluctuations. Mountain wave turbulence may be experienced many tens of miles downwind from the orographic obstruction.

One can now visualize the magnitude of the turbulence detection and prediction problem. Despite the intermittency of turbulence (its lifetime is often 10-15 minutes recurring in the same location every 30 minutes to an hour, roughly), pilots would like a 5-minute warning time. This presents a clear dilemma for meteorologists and developers of instrumentation.

Nature of the Operational Problem and Current Needs

In the round table discussions with fixed committees representing user interests, a large number of specific needs and requirements were identified. To generalize, it was evident that aviation technology has moved far ahead of the technology relating to the prediction and detection of turbulence.

The following is a summary of problems and user needs discussed during committee exchanges:

- Turbulence warnings issued to pilots frequently are false alarms. Conversely, many turbulence encounters occur with no advance warning. False alarms and misses are particularly high for general aviation pilots. The problem, of course, relates to the intermittent nature of turbulence.

- Turbulence avoidance policies and practices are inconsistent in the view of some pilots. While safe flight policies recommend turbulence avoidance "at all cost," practices too often result in vectoring aircraft through known or suspected turbulence areas.

- There appear to be inadequacies in the decision-making process a pilot might use on turbulence encounters.

- There is a lack of information on the incidence of turbulence associated with larger-scale weather patterns.

- A well known need exists for an on-board turbulence detection device.

- A need was expressed for the training in turbulence while flying on instruments.

- There is no live practice flight training in turbulence, particularly important for general aviation pilots. Practice in fair weather cumulus was suggested.

- Turbulence appears to be more important for light aircraft in terms of aircraft sturcture and response (increased likelihood of upset), whereas wind shear is the greater hazard for large aircraft due to long spool-up times and increased aircraft mass. This fact points to the need for training to upset in simulators for general aviation pilots, currently nonexistent. General aviation pilots also expressed concern for the lack of textbook training on turbulence--the nature of the meteorological problem and what to do about it.

- Regarding pilot reports of turbulence (PIREPS), an improved flow of this information to the ARTCC meteorologist was desired. PIREPS should be used to define flight avoidance zones and the analyzed information flow back to pilots on improved communication channels through the air traffic controller.

- There is a desire to establish a direct link between the en route pilot and the ARTCC meteorologist.

- It was suggested that all PIREPS be archived for follow-on research studies.

- In the area of on-board turbulence measurement devices, (e.g., vertical accelerometers), there was expressed a need for accelerometers mounted both in the forward and rear sections of large aircraft, improvements in instrument maintenance, and a recommendation made to standardize turbulence sensors and specifications on accelerometer output response.

- Another attempt should be made to standardize terminology. Preliminary measures should be taken to organize, firmly define, and transmit through the aviation community standardized terminology.

- Revive research work on identifying turbulence levels and locations in thunderstorms. This time use microwave Doppler instead of instrumented aircraft to verify turbulence.

- Improved meteorological services to terminal controllers is needed in not only the area of turbulence, but the whole gamut of weather.

- An important need exists to improve communications between various groups serving the aviation industry with weather information. The groups include the National Weather Service, the Flight Service Station, the Air Route Traffic Control Center meteorologists, terminal controllers, and the airline weather centers.

Progress and Developments in the Past Year

Despite the abundance of current problems and needs of the user, there has been significant progress in the past year--progress that cannot yet be objectively evaluated because only the foundation has been set. However, measurable improvements are expected in the near term.

In the area of prediction and map detection of turbulence, the assignment of 38 meteorologists to 13 ARTCC's east of the Rocky Mountains has the promise of a long awaited improvement in weather services to pilots en route. Some additional time is necessary to bring meteorologists up on the aviation weather education curve, enhance detection and communication hardware, develop models, improve handling of PIREPS, and gain the confidence of controllers. Except for hardware improvements, most of this improved service is ongoing at the New York Center where meteorologists have been employed for some years. Real improvements nationwide will certainly be expected in the near future.

For the general aviation pilot, substantial improvements are in store for the labor intensive FSS where automation is badly needed. The proposed data tap to the Automated Facilities Observations System (AFOS) will provide real-time digital output presently available on paper facsimile and teletype.

In the area of detection, the infrared radiometer is scheduled for operational testing this year. Several aircraft will be equipped with this device and an evaluation will be forthcoming soon. Other promising sensors are also being developed for future operational use: the microwave Doppler, the laser Doppler, and the microwave temperature profile sounder.

There have been substantial improvements in simulation models, including newly employed turbulence components and moments necessary to enhance training.

There also appears to be a quick and smooth flow of information recently published by researchers to the user.

Progress has been made in the study of spanwise turbulence.

Lastly, a new development with the FAA occurred shortly after the conclusion of the 1979 Workshop. This agency is embarking on a task to use data from the proposed Discrete Address Beacon System (DABS) as input to an objective analysis scheme which will map the wind in the three-dimensional troposphere. Initially designed to map winds at mesoscale in the terminal area when the DABS system becomes operational in 1981, the use of DABS and the objective analysis method using DABS inputs on a large scale implies that the whole atmosphere over the United States may eventually be mapped. Thus, real-time analysis outputs will reveal turbulence and wind shear zones and will provide this information directly to pilots via the DABS data up-link.

It is evident that substantial improvements in all facets of detection, prediction, and communication of turbulence information are on the horizon.

SECTION VIII

CONCLUDING REMARKS







CONCLUDING REMARKS

Walter Frost

The University of Tennessee Space Institute

The committee chairmen are to be congratulated on their fine summaries of the committee discussions. Although there was potential for appreciable overlap of subject areas, because of the nature of the topics, each chairman has covered only those facts which pertain to his topic, which is very commendable. I would like to thank the committee chairmen and the committee members for their time and effort. Also, I would like to express my appreciation to the authors of the excellent overview papers presented earlier this week. I believe these papers touched upon exactly the type of information needed to stimulate the kinds of discussion we hoped to achieve at the workshop.

I would like to request your comments on the workshop, either verbally here or maybe in writing later. In conversations with many of you, your comments have been mostly complimentary and have indicated that this workshop and preceding workshops have provided a valuable service to the aviation community. I am always interested in learning whether we are achieving everything we can from one of these programs. I believe some very good things have happened here at this workshop, and some of the results for which we were looking have occurred. As an example, Jim Banks has told me that he learned things relative to air traffic control which he had not thought of before, particularly in the meeting with the Icing Committee, a committee that he had originally thought would have no interchange with his committee. This is precisely the type of results we wish to achieve, that is, to bring to the awareness of other segments of the system the meteorological problems that can occur. The Airport Committee also expressed the fact that they learned measurements of temperature and humidity and other meteorological parameters can be appreciably different if measured at one end of the runway as contrasted to the other. Again, this type of exchange of information which provides an awareness of meteorological effects is the purpose for these workshops. Additional segments of the aviation community are now thinking about problems of which they were not aware before, and perhaps they no longer laugh at regulations for which they can now see some meaning.

I was encouraged also by Tom Incrocci's comments that the Air Force now uses a slightly different procedure relative to performance in wind shear for one of their new aircraft because of comments they received from Jack Bliss in our first workshop here three years ago. I realize that these regulations were not changed solely due to the input from the workshop, but certainly the change was, in part, an outgrowth from it. As Jack Enders pointed out earlier when he introduced the objectives of this year's program, a specialists' workshop on icing was an outgrowth from our first workshop; and these combined meetings have resulted in a major icing program beginning at NASA Lewis Research Center. So the

workshops are having an impact. I believe this impact is achieved basically because of the learning process that takes place through the interchange of ideas during the committee discussions. This format, i.e., committee meetings between highly disciplinary groups, is extremely effective for disseminating information. What concerns me a little, however, is that because of the makeup of the workshop the discussion groups must be relatively small, and in that sense I wonder how much of the information gets passed on in the larger scale. I realize the information diffuses out, but it is probably a slow diffusion, and I would welcome your suggestions for ways that we can diffuse it faster. All of you who attend these workshops are in a position to take back what you have learned and impact programs within your own agencies. Therefore I believe the workshops on an annual basis are good, but we can perhaps make them better from your inputs.

There were some comments from the attendees about certain weaknesses in the workshop. For example, many of you felt that there were not enough human factors people here. That is true. We had scheduled a fairly large representation of human factors types, but at the last minute some of these people had to cancel. Some of you felt we needed more research type people from the NWS. Again, due to the accident at Three-Mile Island in Pennsylvania, some of the people scheduled to come here went there instead in response to the national crisis.

There was also a noticeable lack of small plane manufacturers this year, probably due to poor planning on my part. Last year we had a lack of major airline people, so we concentrated our effort in that area and maybe overlooked the smaller manufacturers a little. We will compensate for that next year.

Max Karant pointed out to you in the banquet address that we should get some pilots to talk to us. It is interesting--I made some quick calculations--that about 20% of our group are commercial airline pilots who fly regularly and 60-70% of you attendees currently hold private pilot licenses or have flown in the past. So, in response to Max's comments, I don't know how to do better in that regard. We have a lot of pilots here and they are talking to us.

One of the results from the workshop in which I would like to see somewhat more progress, however, is in answering the question, "How?" I hear frequently: "They need to do this." and "We need this." What I would like to see come out of the workshop is more on how we do this. Not being involved in the detailed organization of the government agencies, I am not aware of how one goes about getting things done. I would like to see things in a proceedings which perhaps give guidelines in this direction. For example, standard terminology, we all agree, is needed. But what do we do? Where do we start? Do we need a new agency? Or do we need to encourage senators to provide funds to some existing agency to get this done? Or should we approach some of the professional societies to do this? Many of our recommendations, I feel, need some explanation as to how we start.

These questions are some of the things we were trying to imply in our guidelines; for example, who is the responsible agency, what is the transferral process, etc. How one gets these things done I know is a very tough question, but I believe if we could somehow or other organize these workshops so that they could respond a little more in that vein we would double our productivity. As I said earlier, I believe the workshop is a very good thing; it does a lot for us. It would do more, however, if recommendations were made that say how we start and how we get things done as much as what it is we need. If you have suggestions on ways we can orient the workshop to answer the how's as well as identifying the problems and needs, I would certainly appreciate hearing your comments.

Finally, I would like to thank some of the people who have been very helpful in carrying out the logistics of the workshop. Barry Turkel has been most helpful in this role. Let me also tell some of the people here that Barry is an excellent student and is very interested in FAA or accident investigation relative to weather. You might think of recruiting him.

Becky Durocher has also been a very important factor in the organization of the workshop. Many of you have commented on how well it has been organized. Becky has done an immense amount in this regard and I would like to thank her for her efforts.

I would now like to call in succession on our Organization Committee to pass on a few concluding remarks to you.

Thank you again and I hope we have a fourth workshop and you will be back here with us.

CONCLUDING REMARKS

Dennis W. Camp

NASA Marshall Space Flight Center

My remarks will be considerably briefer than those of Dr. Frost. Mainly, what I have to say is concerned with my opinion of this workshop and how it accomplished what it did. I have heard several people say it was a successful workshop and in my opinion it was indeed successful. The reason it was a success and accomplished what it did was not because of the organizing committee but because of you: the committee chairmen and the committeemen. Without you we would not have had a workshop and thus I sincerely appreciate each and every one of you. Thank you for coming and now I'll turn it over to Joe Sowar for his comments.

CONCLUDING REMARKS

John H. Enders

NASA Headquarters

I won't bother to stand up, because I don't want to keep you any longer. You all heard Jules Bernard's joke this morning about fishing, and that suggested to me that this workshop has thrown the dynamite stick into our laps, so I'll just ask: "Are you going to sit here talking all day or are you going to get out there and fish?" When you get out there, back at your jobs, spread the word on what you learned here, build up enthusiasm for this type of workshop. I think the idea of getting people together from different segments of the system who have a common interest in weather and safe operations can cause marvelous things to happen in the next three or four years. I appreciate your support of this workshop, and I hope that next year we'll have an even better one than we had this year. Have a safe trip home!

APPENDICES

APPENDIX A

THIRD ANNUAL WORKSHOP ON
METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

List of Acronyms

ADAP	AIRPORT DEVELOPMENT AID PROGRAM
ADF	AUTOMATIC DIRECTION FINDER
AFB	AIR FORCE BASE
AFOS	AUTOMATION OF FIELD OBSERVATIONS AND SERVICES
AFSC	AIR FORCE SYSTEMS COMMAND
AIRMET	AIRMAN METEOROLOGICAL ADVISORY
ALPA	AIR LINE PILOTS ASSOCIATION
ALWOS	AUTOMATED LOW-COST WEATHER OBSERVATION SYSTEM
AOPA	AIRCRAFT OWNERS AND PILOTS ASSOCIATION
APCL	ATMOSPHERIC PHYSICS AND CHEMISTRY LABS
ARTCC	AIR ROUTE TRAFFIC CONTROL CENTER
ATA	AIR TRANSPORTATION ASSOCIATION
ATC	AIR TRAFFIC CONTROL
ATCA	AIR TRAFFIC CONTROLLERS ASSOCIATION
ATIS	AUTOMATED TERMINAL INFORMATION SERVICE
AWANS	AUTOMATIC WEATHER AND NOTAM SYSTEM
AWES	AVIATION WEATHER SYSTEM
AWS	AIR WEATHER SERVICE
BA	BRITISH AIRWAYS
BALPA	BRITISH AIR LINE PILOTS ASSOCIATION
BCAL	BRITISH CALEDONIAN AIR LINES
BCD	BINARY CODED DECIMAL
BMO	BRITISH METEOROLOGICAL OFFICE

CAA	CIVIL AIR AUTHORITY
CAI	COMPUTER ASSISTED INSTRUCTION
CAT	CLEAR AIR TURBULENCE
CCTV	CLOSED CIRCUIT TELEVISION
CEGB	CENTRAL ELECTRICITY GENERATING BOARD
CMSU	CENTER WEATHER SERVICE UNITS
CRT	CATHODE RAY TUBE
CSD	CONVECTIVE STORM DIVISION
CTOL	CONVENTIONAL TAKE-OFF AND LANDING AIRCRAFT
CY	CALENDAR YEAR
d	DIAMETER
DABS	DIRECT ADDRESS BEACON SYSTEM
DALE	DIGITAL ANEMOGRAPH LOGGING EQUIPMENT
DOD	DEPARTMENT OF DEFENSE
EDT	EASTERN DAYLIGHT TIME
EFAS	EN ROUTE FLIGHT ADVISORY SERVICES
EMP	ELECTROMAGNETIC PULSE
ERL	EARTH RESOURCES LAB
ETABS	ELECTRONIC TABULAR DISPLAY SUBSYSTEM
FAA	FEDERAL AVIATION ADMINISTRATION
FAR	FEDERAL AVIATION REGULATION
FAX	FACSIMILE
FDR	FLIGHT DATA RECORDER
F&E	FACILITIES AND EQUIPMENT
FOFAX	FORECAST OFFICE FACSIMILE
FSS	FLIGHT SERVICE STATION
FSSP	FORWARD SCATTERING SPECTROMETER PROBE
FY	FISCAL YEAR

GA	GENERAL AVIATION
GOES	GEOSTATIONARY OPERATIONAL ENVIRONEMNTAL SATELLITE
HISS	HELICOPTER ICING SPRAY SYSTEM
IAS	INSTITUTE OF ATMOSPHERIC SCIENCES
ICAO	INTERNATIONAL CIVIL AVIATION ORGANIZATION
IFR	INSTRUMENT FLIGHT RULES
ILS	INSTRUMENT LANDING SYSTEM
INS	INERTIAL NAVIGATION SYSTEM
IR	INFRARED
IRT	ICING RESEARCH WIND TUNNEL
ITA	INDEPENDENT TELEVISION AUTHORITY
JFK	JOHN FITZGERALD KENNEDY INTERNATIONAL AIRPORT
LLWAS	LOW LEVEL WIND ALERT SYSTEM
LLWS	LOW LEVEL WIND SHEAR
LWC	LIQUID WATER CONTENT
MEA	MINIMUM EN ROUTE ALTITUDE
MINI SESAME	MINI SEVERE ENVIRONMENTAL STORMS AND MESOSCALE EXPERIMENT
MSL	MEAN SEA LEVEL
NADIN	NATIONAL AIRSPACE DATA INTERCHANGE NETWORK
NAFEC	NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER
NAMFAX	NATIONAL AND AVIATION METEOROLOGICAL FACSIMILE
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NAVAID	NAVIGATION AID
NCAR	NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
NECHE	NORTHEAST COLORADO HAIL EXPERIMENT
NHRE	NATIONAL HAIL RESEARCH EXPERIMENT
NOAA	NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOTAM	NOTICE TO AIRMEN

NSF	NATIONAL SCIENCE FOUNDATION
NTSB	NATIONAL TRANSPORTATION SAFETY BOARD
NWS	NATIONAL WEATHER SERVICE
OAP	OPTICAL ARRAY SPECTROMETER PROBE
OAT	OUTSIDE AIR TEMPERATURE
OPR	OFFICE OF PRIMARY RESPONSIBILITY
PATCO	PROFESSIONAL AIR TRAFFIC CONTROL ORGANIZATION
PCIA	PORT COLUMBUS INTERNATIONAL AIRPORT
PDR	PULSED DOPPLER RADAR
PIREP	PILOT REPORT
PMS	PARTICLE MEASURING SYSTEM
PSI	POUNDS PER SQUARE INCH
RAE	ROYAL AIRCRAFT ESTABLISHMENT
R&D	RESEARCH AND DEVELOPMENT
RRL	RADAR RESEARCH LABORATORY
RVR	RUNWAY VISUAL RANGE
SAAB	SVENSKA AEROPLAN AKTIEBOLAGET (SWEDISH AIRPLANE COMPANY)
SAE	SOCIETY OF AUTOMOTIVE ENGINEERS
SAMOS	SEMI-AUTOMATED METEOROLOGICAL OBSERVATION SYSTEM
SDSM&T	SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
SESAME	SEVERE ENVIRONMENTAL STORMS AND MESOSCALE EXPERIMENT
SIGMET	SIGNIFICANT METEOROLOGICAL ADVISORY
TIPS	TERMINAL INFORMATION PROCESSING SYSTEM
TRIP	THUNDERSTORM INTERNATIONAL RESEARCH PROJECT
UCAR	UNION CARBIDE
US	UNITED STATES
USAF	UNITED STATES AIR FORCE
UTSI	UNIVERSITY OF TENNESSEE SPACE INSTITUTE

VFR	VISUAL FLIGHT RULES
VOR	VHF OMNI-DIRECTIONAL RANGE
VOR/TWEB	VHF OMNI-DIRECTIONAL RANGE/TRANSCRIBED WEATHER BROADCAST
WAVE	WIND, ALTIMETER AND VOICE EQUIPMENT
WFMU	WEATHER FIXED MAPPING UNIT
WPM	WORDS PER MINUTE

APPENDIX B

THIRD ANNUAL WORKSHOP ON
METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

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